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13. ABSTRACT

A ground based optical system is described in detail. The system consists of a manual sighting station, main pedestal, television subsystem, control console, video console, timing system and digital data handling system. Its primary function is to point a Fabry-Perot Interferometer to programable points in the far field and record all position, time, house-keeping and optical information.

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Technical Report
January 1972

Prepared By
Rome Air Development Center
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Griffiss Air Force Base, New York 13440

PROJECT SECEDE

SECEDE II

FOREOPTICS AND RECORDING EQUIPMENT SUPPORT - OPTICAL INTERFEROMETER

General Electric Company

Sponsored by
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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ROME AIR DEVELOPMENT CENTER (AFSC)
GRIFFISS AIR FORCE BASE, NEW YORK 13440

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RADC-TR-72-76
TECHNICAL REPORT
JANUARY 1972

SECEDE II
FOREOPTICS AND RECORDING EQUIPMENT SUPPORT - OPTICAL INTERFEROMETER

Raymond H. Lambert

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Contract Number: F30602-71-C-0064
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FOREWORD

The Interim Report - Secede II - Foreoptics and Recording Equipment Support - Optical Interferometer includes the work performed by the General Electric Company, Space Sciences Laboratory during the period May 1, 1970 through March 3, 1971. During this period a ground based optical pedestal with all associated control and data recording equipment was constructed to support the Optical Interferometer measurements of the Barium ion radiation in the Secede II experiments. Not included in this report is the work performed by the University of Pittsburgh personnel on the construction of and the measurements by the interferometer. Data reduction of the measurements made during January 1971 will be reported in a separate report.

PUBLICATION REVIEW

This technical report has been reviewed and is approved.

RADC Project Engineer

Richard A. Schneible

RADC Contract Engineer

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TECHNICAL SUMMARY

Background

On the basis of the Secede III optical interferometer measurements, it was evident that several important changes and improvements were needed in this experiment for future Secede observations. Measurements previously made by Dr. Biondi,of the University of Pittsburgh,of the Barium ion and neutral clouds were desired to be made at higher spatial resolution than the two milliradian field of view previously employed. The Secede III measurements also showed that an improved data recording system is necessary to facilitate the automatic processing and reduction of the measurement data.

The objectives of this contract were to provide the foreoptics, data handling and recording system, a servo driven mount, control console and optical sighting station for the Fabry Perot Interferometer designed by the University of Pittsburgh in support of the Secede II Measurements Program. In addition to the design and fabrication phase of the program, the necessary support for on site measurements during the month of January at Wewahitchka, Florida, was provided. The total period of performance on this contract was from May 1970 through March 1971.

System Description

The Secede II foreoptics and recording equipment support - optical interferometer system is basically a self contained optical tracking station. The nucleus of the system is a reconditioned search light pedestal which was modified to carry the necessary foreoptics for the Fabry Perot Interferometer. A particular design constraint was that the interferometer could not be tilted from the vertical, however, must be employed to make measurements of a large barium vapor cloud. The foreoptics consisted of a

modified Dahl-Kirkham design of 16 inch diameter. In addition to the primary optical system, a second co-boresighted flat mirror could be placed in such a manner that the interferometer could view the cloud directly. The mode of operation is selectable from the master control console. In this way either high resolution measurements through the primary system or lower resolution measurements through the flat mirror could be made.

In addition to the interferometer and optical system, the pedestal carried a single photometer system, optical calibration, and image orthicon television system. The photometer served to measure the total energy falling on the interferometer aperture. The optical calibrator was used to align and calibrate the interferometer system immediately before and after each series of measurements. A direct view of the barium cloud was provided by the television system on a display at the control console. Superimposed upon this display were range timing and actual pointing coordinates.

The operator of the control console remotely directs the pedestal to any desired position. An analog scan computer could be programmed to perform single or multiple, single linear scans, raster type scans, or have the capability of being modified to accept external radar pointing signal (this mode was not implemented). A manual sighting station was also provided for initial cloud acquisition and carried a slow framing 35 mm camera for documentary photographs of the overall source geometry. A third console contained video recording equipment and the necessary electro-optical systems for the digital type displays at the control console. A timing console was also provided. This console housed an Astrodata timing system which had the capability of accepting IRIG B time code or-in case of failure - had the ability of generating its own local timing.

A digital data handling and recording system was designed and built to accept all measurement information. This includes all data from the Fabry Perot, the photometer, range time, azimuth and elevation angles, and all house keeping functions. The system interfaced with an incremental digital tape recorder providing an IBM compatible data format to facilitate data reduction. In addition to the digital tape recorder, the recording console housed all the controls for the Fabry Perot Interferometer and several of the servo control functions for the main pedestal.

Three men are necessary for the proper operation of the Secede II system. The operator at the manual sighting station is responsible for initial acquisition and for pointing out events of interest within the Secede cloud as the mission develops. The operator of the control console is responsible for the pointing direction of the pedestal and the programming of proper scanning direction and length across the Secede cloud. The operator of the recording console, controls all the Fabry Perot functions during the measurement period. Through experience it was found that a fourth team member is highly desirable to function as a test director and coordinate the activities of the other three crew members. This function however, was in some cases provided by the operator of the optical sighting station.

Measurements were made during January 1971 of six Secede II barium clouds. Results were obtained on all but one of the tests which was launched during the full daylight condition. Data reduction and analysis is presently being performed under separate contract.

1.0 INTRODUCTION

This report describes the design and appropriate analysis supporting this design of the Secede II - Foreoptics Pointing and Recording System. This project was performed under the direction of Mr. T. Pitts of Rome Air Development Center and Mr. R. Lambert of the General Electric Company.

The system consists of a main support pedestal which supports the optical, calibration, Image Orthicon and photometer systems. The pedestal can be directed from either of two positions 1) the control console and 2) a manual sighting station. A control system, consisting of control transformers and synchro generators was designed and fabricated. In addition an analog scan computer was designed and incorporated into the control system, which is programmed by the console operator. An Image Orthicon camera system forms an integral part of the pointing and control loop. Through use of the display on the control console the operator can direct the main pedestal to a desired location via a joystick.

A digital data handling system was fabricated to format and record the various outputs from the measuring instruments. Control and housekeeping functions are also recorded. A video tape system is also employed to record the output of the Image orthicon, azimuth and elevation positions and time of day. A recording console which not only houses the digital tape recorder but also the Fabry Perot Control Station and power amplifiers for the main pedestal, is described.

This report does not describe each detail of the various trade off decisions which had to be made before arriving at the final system configuration. However, it does

describe in some detail the necessary design analysis performed on critical subsections of the Secede II systems design. The main thrust of this report is to provide under one cover a systems and subsystems description and detailed electrical interconnection schematics. Detailed component descriptions are only given for major subsystems specifically designed for this system. Drawings of the mechanical assemblies are provided separately.

2.0 OPTICAL SYSTEM

The optical system provides two separate sets of mirrors, each reflecting energy into the interferometer. Each optical system is designed so that the optical axis of the system can be aligned parallel to the mechanical axis (elevation only) of the main pedestal. By virtue of this design, the interferometer is neither translated nor rotated as the mount is scanned in elevation, thus preventing any possible sag of the Fabry Perot plates. The two systems are designated Wide Field and Narrow Field, respectively.

In the Wide Field mode, a plane surface elliptical mirror is placed in front of the objective lens of the Fabry Perot, the surface at a 45° angle to the interferometer optical axis. This mirror has the following characteristics.

Major Axis - - - - - - - - - - - 6.4 inches

Minor Axis - - - - - - - - - - - 4.5 inches

Thickness - - - - - - - - - - - .5 inches

Material - - - - - - - - - - - Pyrex

Surface Accuracy - - - - - - - 1/4 wave

Reflectivity - - - - - - - - - - - 98% $\pm$ 1%

The mirror is bonded by silicon rubber to a Textolite block which can be pivoted about a single point. Textolite was chosen for its thermal expansion properties which closely match those of pyrex glass. Three point screw adjustments are provided for optical alignment. The entire assembly is mounted on a sliding block retained by a precision dovetail mount. The dovetail slide is in turn rigidly attached to the

main elevation bridge. Changing from Wide Field to Narrow Field mode is accomplished by sliding the mounting block/mirror along the dovetail through use of a motor driven lead screw. The entire assembly resembles an elevator. In the up position the interferometer looks through a light tunnel into the primary telescope; in the down position, at the wide field mirror. A fixed stop is provided to ensure reproducibility of position in the wide field mode.

The narrow field optics are shown in Figure 2-1, "Secede Telescope". They consist of three reflecting surfaces, primary, secondary and tertiary mirror. The tertiary has identical characteristics to the wide field mirror, and serves to deflect the interferometer optical axis 90° degrees. Mechanical mounting is similar to the wide field mirror with three point screw adjustments of alignment of optical/mechanical axis.

The main telescope is a Dahl-Kirkman (ellipsoidal primary, spherical secondary) design, used as a beam expander; that is, parallel light into the primary exits parallel from the secondary. A diameter of 16 inches is choosen so as to maintain the thru-put ($A \Omega$) of the University of Pittsburgh Interferometer. By decreasing the field of view by a factor of 4, to 1/2 milliradian, a diameter of 16 inches can usefully be employed. Characteristics of the primary and secondary are as follows.

	Primary	Secondary
Diameter	15.78 inches	4.5 inches
Focal Length	62.78 "	-16 "
Thickness	2.5 "	.5 "
Material	Pyrex	Pyrex

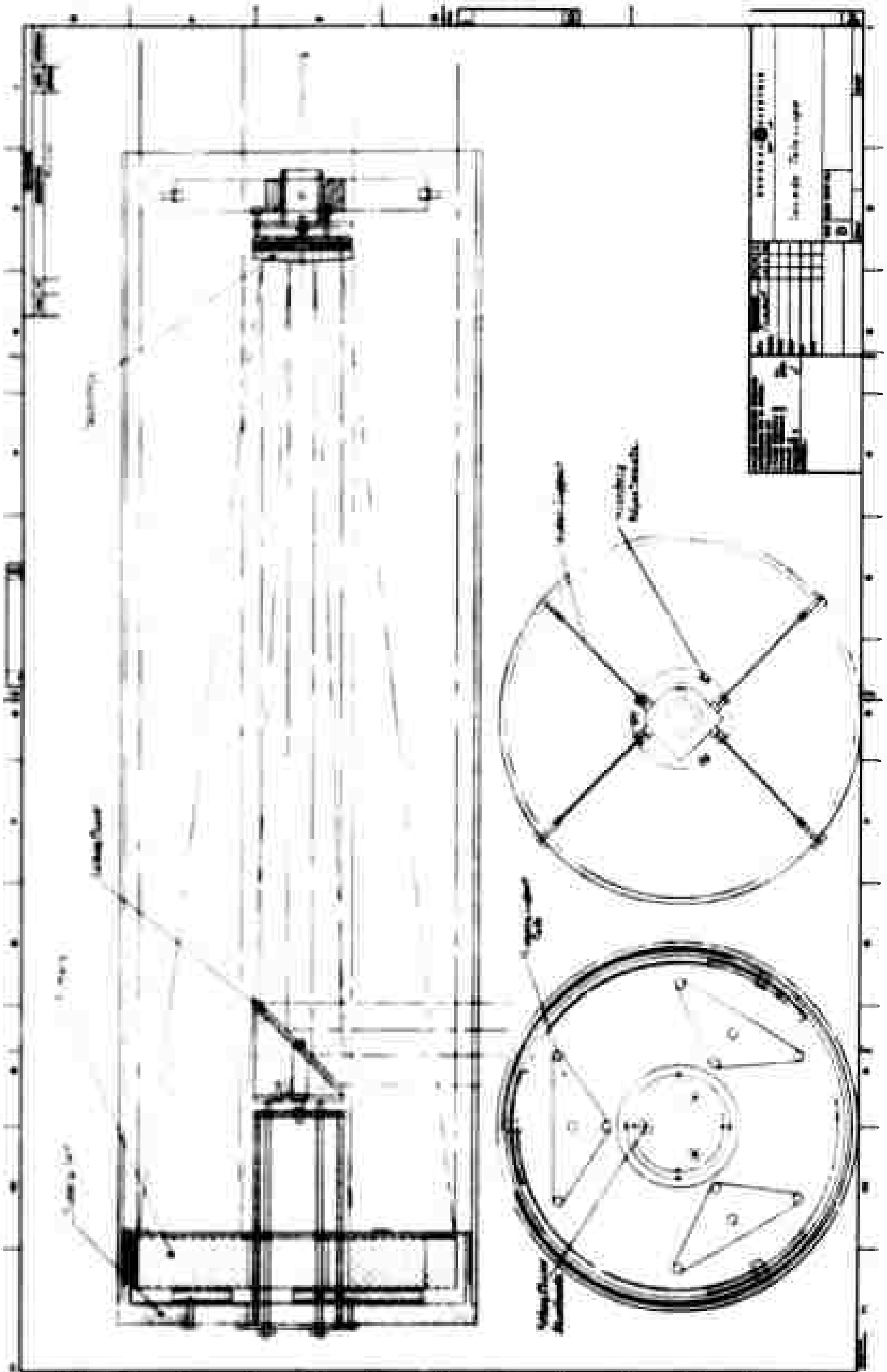


Figure 2-1. Secede Telescope

	Primary	Secondary
Figure	Ellipsoidal	Spherical Convex
Eccentricity	.8655	-1
Surface Accuracy	1/4 wave	1/4 wave
Reflectivity	98 ± 1%	98 ± 1%
Center Hole	5" inches	N. A.
Centering	± 0.010 inches	N. A.

The secondary is again bonded to a Textolite spacer which in turn is secured to an aluminum plate. Again three screw adjustment about a precision pivot are provided. This assembly is mounted on a stainless steel tube which slides axially within the brass spider block. In this way, spacing between the primary and secondary mirrors can be adjusted; ± 1 inch. The four spider legs are attached in such a manner that the force exerted along the legs is tangent to the circumference of the sliding tube. An extremely rigid secondary support is thus achieved.

The primary mirror cell employs multi pointed balance supports to minimize image distortions due to mirror sag. Each of the three balanced plates supports the mirror at three points, each plate being balanced at a single point, D/3 from the center axis. The primary is restrained within the cell at three point, spaced at 120° around the perimeter. At each restraining point, two set screws exert pressure against a stainless steel leaf spring spaced from the primary by 1/16 inch rubber. Stresses at these points are thereby minimized. Three retaining tabs are provided to prevent a catastrophic failure due to a severe shock being imparted to the system with the telescope pointed downward.

The telescope tube is a rolled and welded 3/8 inch aluminum tube. Two 1 inch steel straps attach the telescope to the main pedestal. Alignment is maintained by two pins on the main bridge and two corresponding holes in the telescope tube.

2.1 Calibration Optics

To align the Fabry Perot plates, a single frequency mode locked in Ne-He laser was employed. A relay system was used to direct the energy from the laser, mounted between the main trunion arms, to the Fabry Perot via the wide field mirror. Three front surface mirrors mounted within square sheet metal tubing, reflected energy from the laser to the wide field optics. Rotating the main mount to an elevation angle of -10^{o} caused the interferometer to look into the relay optics. Each relay mirror was provided with a three point adjustment. Calibration can be performed at any azimuth position.

2.2 Optical Alignment Procedure

Initial alignment of the primary telescope system is performed in the laboratory. Spacing between the primary and the secondary mirror for proper collimation is determined by illuminating the primary with a collimated source of energy and adjusting the secondary until a collimated beam exits from the tertiary. A special test fixture was fabricated to hold the primary cell in a vertical position to facilitate these measurements. After determination of the spacing, holes were cut in the telescope tube to position the secondary mirror at the proper point. The telescope was then assembled. The collimator was positioned inside the telescope barrel so that while assembled a collimated source of energy would rotate with the telescope tube. An image of the collimator aperture is formed at the focal plane of the Fabry Perot.

After mounting the telescope system on the main pedestal the system is elevated so that the image of a star is formed at the exit aperture of the Fabry Perot system. The secondary spacing is then critically adjusted so that the smallest image of the star is formed. The primary optics is thereby adjusted so that collimated light in yields the best collimated light at the exit aperture. The calibration collimator is then switched on. The image of the collimated aperture is observed at the focal plane of the interferometer as the telescope is swung in elevation. Proper alignment is achieved when the image of the collimator aperture is stationary, that is it does not move, as the bridge is swung in elevation. This means that the optical axis defined by the axis of the collimator is parallel to the mechanical axis; that is, elevation axis of the main pedestal. This alignment is performed by adjustment of the tertiary and is necessary to prevent boresight errors at various angles of elevation. The interferometer is then mechanically adjusted so that the exit aperture is centered to the image of the collimator. The telescope is then elevated to a fixed far field source so that the image of this source is superimposed upon the image of the collimator. The mount is then locked at this position. The Wide Field/Narrow Field elevation is then placed in the Wide Field mode and the Wide Field mirror adjusted so that the image of the fixed source is placed on the exit aperture of the interferometer.

The final alignment is to insure that the laser calibrator through the relay system fills the entire aperture of the Fabry Perot interferometer. The bridge is brought to the calibrate position. The three relay mirrors are adjusted as necessary.

3.0 CONTROL CONSOLE

The Master control console provides a single position from which all the various functions of the mount can be controlled. The console houses the television monitor, scan computer, image orthicon remote control panel, the data handling system, video mixer, and a control panel. The main function of the operator at this position is to implement the various scanning modes and direction of scan for the main pedestal. In addition, the operator selects the appropriate I.O. filter. He also controls the position from which the tracking commands originate, be they from the manual station control transformers, the manual station variable resistors, or he can assume control himself via the joystick. In addition, he may implement a calibration sequence and also select the mode of operation whether it be wide field or narrow field.

A cursor is mounted on the front of the television monitor which can be rotated to any angle via a 2 inch knob on the left hand side of the panel. The cursor controls the direction of scan. A drawing of the control panel is shown in Figure 3-1, "Control Panel - Secede II".

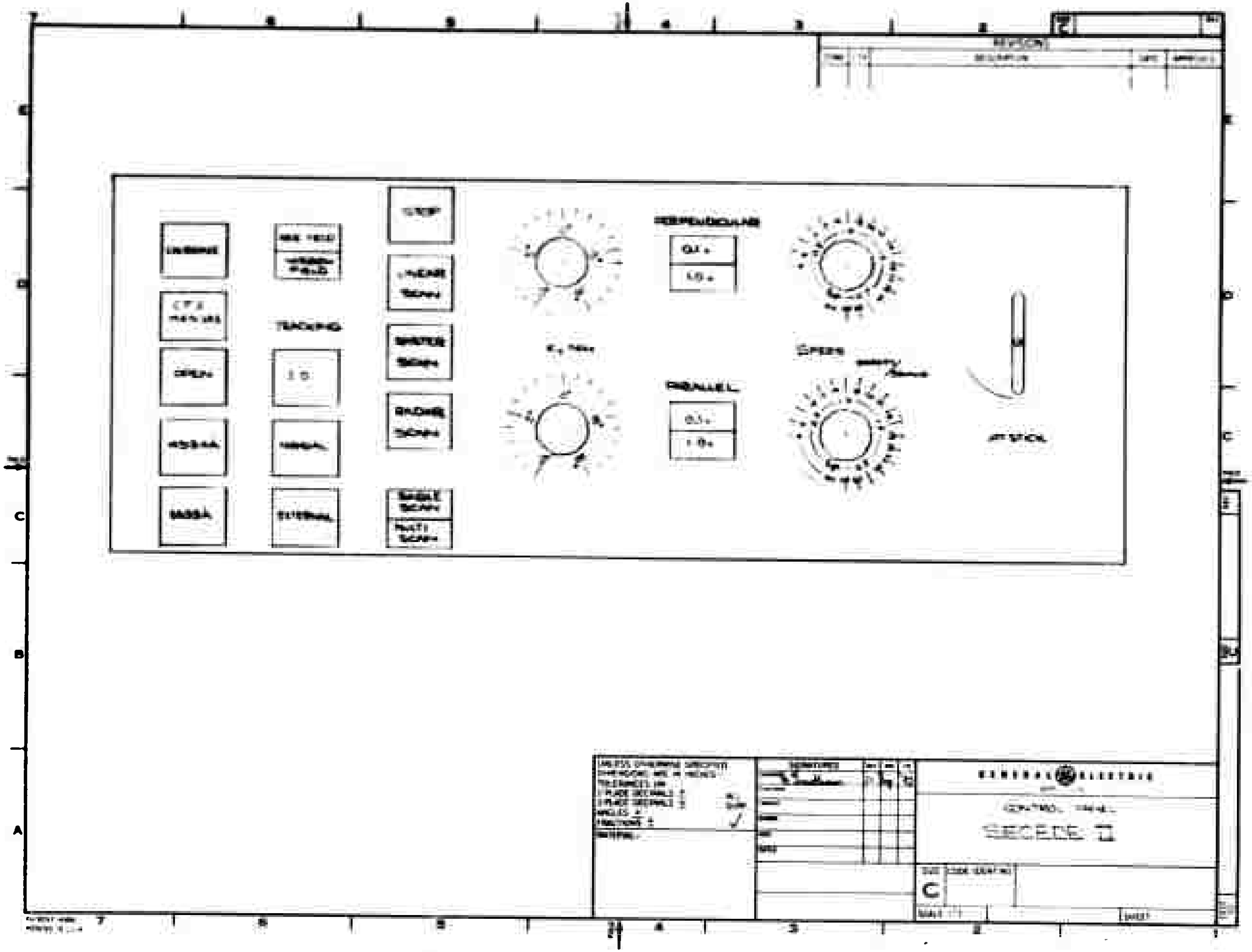


Figure 3-1. Control Panel - Secede II

3.1 Control Panel Switch Functions

I.O. Filter Controls	(3) Switches
Switch Marking	**Function**
Open	1. Inserts clear aperture and causes removal of any other filter
	2. Lights on depression
	3. Is held by solenoid when depressed
	4. Releases either of the other two filter switches
	5. Inserts a "1" into position 23-B and a "0" into position 23-A of digital tape
4934 Å	1. Inserts 4934Å filter and causes removal of any other
	2. Lights on depression
	3. Is held by solenoid when depressed
	4. Releases either of the other two filter switches
	5. Inserts a "0" into position 23-B and a "1" into position 23-A of D. T.
5535 Å	1. Inserts 5535 Å filter and removes any other filters
	2. Lights on depression
	3. Is held by solenoid when depressed
	4. Releases either of the other two filters switches
	5. Inserts a "1" into position 23-B and a "1" into position 23-A of digital tape
Tracking Controls	(3) Switches
I.O. Track	1. Causes mount direction control to be switched to the velocity joy stick on the control panel.
	2. Is lighted and held by solenoid when depressed

Scan Type Control — (4) Switches

Stop

1. Causes any scan to terminate and resets K_1 and K_2 generators to 0
2. Is lighted and held by solenoid when depressed
3. Releases the solenoids of other scan switches
4. Places "0" in position 22-4 and "0" in 22-2 of digital tape.

Linear Scan

1. Causes K_2 generator to be activated
2. Is lighted and held by solenoid when depressed
3. Releases the solenoids of other scan switches
4. Places "1" in position 22-4 and "0" in 22-2 of digital tape

Raster Scan

1. Causes K_1 and K_2 generators to be activated
2. Is lighted and held by solenoid when depressed
3. Releases solenoids of other scan switches
4. Places a "0" in position 22-4 and "1" in 22-2 of digital tape

Radar Scan

1. Presently undefined
2. Is lighted and held by solenoid when depressed
3. Releases the solenoids of other scan switches
4. Places "1" in position 22-4 and "1" in 22-2 of digital tape

Mode Control — (1) Switch (2) Positions

Single Scan
Multi Scan

1. In single scan mode this control allows only one cycle of any scan type. When scan is finished, "stop" switch should be activated
2. Multi Scan permits an infinite number of identical scans to be executed
3. Is lighted appropriately
4. No record is made of this switch placement

3. Releases the solenoid of either of tracking switches

4. Inserts a "1" into position 21-B and a "0" into position 22-A of D. T.

Manual

1. Causes mount direction control to be switched to the manual

2. Is lighted and held by solenoid when depressed

3. Releases the solenoids of either of the other two tracking switches.

4. Inserts a "1" into position 22-B and a "1" into position 22-A of digital tape

External

1. Causes mount direction control to be switched into the external position

2. Is lighted and held by solenoid when depressed

3. Releases the solenoids of either of the other two tracking switches

4. Inserts a "0" into position 22-B and a "1" into position 22-A of digital tape.

Optics Field of View Switch — (2) Positions

Wide Field

Narrow Field

1. Activates drive motor for sliding 45° mirror on main mount

2. Is lighted appropriately to function

3. In "Wide Field" mode, places a "0" in position 22-8 of D. T.

4. In "Narrow Field" mode, places a "1" in position 22-8 of D. T.

Calibration Switch — (2) Positions

Calibrate

1. Activates drive motor of 45° mirror for wide field of view

2. Places mount direction control to predetermined elevation setting

3. Is lighted when depressed

4. Places a "1" in position 23-8 of digital tape

Scan Rate Multipliers (2) Switches

$\frac{.1\,X}{1\,X}$ One switch for K_1
One switch for K_2

1. Selects appropriate range for K_1 or K_2
2. Is lighted appropriately
3. No recording

Scan Excursion Switches (2) Each Rotary Pots

Perpendicular length
Marked 0 . . . . . 20^{o}

1. Controls maximum excursion of K_2t
2. Back lighted skirt

Parallel Length
Marked 0 . . . . 20^{o}

1. Controls maximum excursion of K_1t
2. Back lighted

Scan Speed Control (2) Switches
Rotary 20 positions

1) Perpendicular speed
Marked 0 - 4 degrees/sec

1. Controls K_2 rate
2. Back lighted

2) Parallel Speed
Marked 0 - 4 degrees/sec

1. Controls K_1 rate
2. Back lighted

Joystick

1. Control azimuth and elevation rates
2. Rate of speed is proportional to position of stick
3. Steers center of cursor to choosen point

CT'S Manual (2) Positions

1. Causes mount control to switch to control transformers in manual mount
2. Lighted when depressed only
3. Position not recorded

3.2 Control Console Wiring Details

The following tables contain the detailed information of the point to point wiring and the wiring of each of the terminal boards in the control console. Included is the control for the Wide Field/Narrow Field elevator (Figure 3-2). Detailed schematics of the major instruments are too lengthy to be incorporated in this report. Such information can be obtained from the Operations Manual for each component.

CONTROL CONSOLE - WIRING DETAILS

D. H. S.	Function	PT02SE-22-55P
J21-8	Gap in Process	A
J21-T	Write Rate/Step	G
J21-R	EOR	s
		t
		N
J26-8	$FF1_1$ F. P. Filters	D
J26-4	$FF1_2$	X
J26-18	$FF2_1$	C
J26-14	$FF2_2$	V
J26-B	FF1 Monitor Point	b
J24-9	MF_1 Monitor Filters	c
J24-15	MF_2	p
J24-19	MF_3	P
J26-14	TF_2 Monitor Point	q
J26-19	R_1 Channel Advance Rate	X
J26-15	R_2	B
J26-9	R_3	Y
J21-9	Channel Advance	h
J3-B	SS On/Off	y
J3-V	S On/Off	j
J3-Z	K_2 Reset	EE
J24-13	DMSB	W
J24-17	D_2	U
J24-22	D_3	GG
J24-E	D_4	FF
J24-1	D_5	T
J24-6	D_6	BB
J24-10	D_7	HH

CONTROL CONSOLE - WIRING DETAILS

D.H.S.	Function	PT02SE-22-55P
J24-16	D_8	µ
J24 21	D_9	n
J24-F	D_{10}	Z
J24-A	D_{11}	k
J24-5	D_{LSB}	cc
J3-Z	Range Switch 1	z
J3-Y	Range Switch 1	F
J3-W	Range Switch 1	i
J7-Z	Range Switch 2	S
J7-Y	Range Switch 2	r
J7-W	Range Switch 2	E
J11-Z	Range Switch 3	g
J11-Y	Range Switch 3	M
J11-W	Range Switch 3	a

CONTROL CONSOLE - WIRING DETAILS

	FUNCTION	TB-CC-1	
J2-H	K_1 Cos α	1	
J2-F	K_1 Sin α	2	
J2-P	K_2 Cos α	3	
J2-R	K_2 Sin α	4	
TB-CC-3-7	+24 VDC	5	To Scan Computer
J8-U	K_2	6	
TB-CC-3-8	GND	7	
11D-3	I.O. Track Switch	8	
13D-3	Ex. Track Switch	9	

		TB-CC-2	
15C-3	Calibrate Switch	1	
J1-V	Nikon Framing	2	
J1-U	Nikon Framing	3	
J3-B	S.S. On/Off	4	
J3-V	S. On/Off	5	
J3-2	K_2 Reset	6	
14B-3	WF/NF Switch	7	EV-3
15B-3	Calibrate Switch	8	EV-9

TB-CC-3	
1	115 VAC
2	115 VAC Ret
3	Blank
4	Chassis Ground
5	Chassis Ground
6	Chassis Ground
7	+24
8	Chassis Ground
9	+5
10	-15
11	Chassis Ground
12	+15
13	Chassis Ground

CONTROL CONSOLE - WIRING DETAILS

TB-CC-4

1	Θ_0 (Pot)
2	ϕ_0 (Pot)
3	Θ_F (Pot)
4	ϕ_F (Pot)
5	+10 VDC
6	10 UDC Ret
7	Elevation (Joystick)
8	Azimuth (Joystick)
9	Θ External — not used
10	ϕ External — not used

TB-CC 5

1	K_2 Cos α
2	K_2 Sin α
3	K_1 Cos α
4	K_1 Sin α
5	$-K_1$ Stimulation
6	$-K_2$ o Pots
7	Ground

CONTROL CONSOLE - WIRING DETAILS

MOUNT FILTER CONTROL AND WIDE/NARROW FIELD CONTROL

PT02P-20-16S

A	+24 VDC Ground	TB-CC-1-7
B	+24 VDC	TB-CC-1-5
C	115 VAC	TB-CC-3-1
D	115 VAC Ret	TB-CC-3-2
H	115 VAC	TB-CC-3-1
F	115VAC Ret	TB-CC-3-3
E	+24 VDC	14A-1
G	+24 VDC Ret	TB-CC-1-7
J	5535 Å	10A-1
K	Open	813-3
L		
M	4934 Å	10B-3
N		
P		
R		
S		

CONTROL CONSOLE - WIRING DETAILS

FROM K_1 and K_2 GROUND TO CONTROL PANEL

Cos α	K_1	J5-U	
Sin α			
Sin α	K_2	J8-U	
Cos α			
K_1 + Max	K_1D_c	J2-4	
K_2 + Max	K_2D_c	J2-5	#1 Are deenergized (normally open)
K_1 Cos α	Buffered	J2-7	
K_1 Sin α	Buffered	J2-6	
K_2 Cos α	Buffered	J2-13	#2 Closed
K_2 Sin α	Buffered	J2-14	#3 Center Arm
Stop Scan 1C-3		J4-17	
Lin Scan 2C-1		J3-7	
Lin Scan 2C-2		J3-21	
Lin Scan 2D-3		J4-16	
Raster Scan 3C-1		J3-8	
Raster Scan 3C-2		J3-18	
Radar Scan 4C-1		J3-S	
Radar Scan 4C-2		J3-17	
Flasher Relay		J3-W	
Kit X. 1, X1. 0 5A-3		J4-13	
Kit X. 1, X1. 0 5B-3		J4-14	
K_2+ X. 1, X1 6A-3		J6-13	
K_2+ X. 1, X1 6B-3		J6-14	
Mode Control 7A-3		J3-13	
I. O. Filter Open 8C-3		J3-4	
I. O. Filter 4934 9C-3		J3-5	
I. O. Filter 5535 10C-3		J3-6	

CONTROL CONSOLE - WIRING DETAILS

FROM K_1 and K_2 GROUND TO CONTROL PANEL

I.O. Track	11C-3	J3-D
Man. Track	12C-3	J3-E
Ex. Track	13C-3	J3-F

CONTROL CONSOLE - WIRING DETAILS

SCAN SPEED SWITCHES

K_1 Switches	K_1/K_2 Generators
1 A_1	J4-2
1 B_1	J4-4
1 C_1	J4-5
1 D_1	J4-6
1 A_2	J4-7
1 B_2	J4-8
1 C_2	J4-9
1 D_2	J4-10

K_2 Switches	
2 A_1	J6-2
2 B_1	J6-4
2 C_1	J6-5
2 D_1	J6-6
2 A_2	J6-7
2 B_2	J6-8
2 C_2	J6-9
2 D_2	J6-10

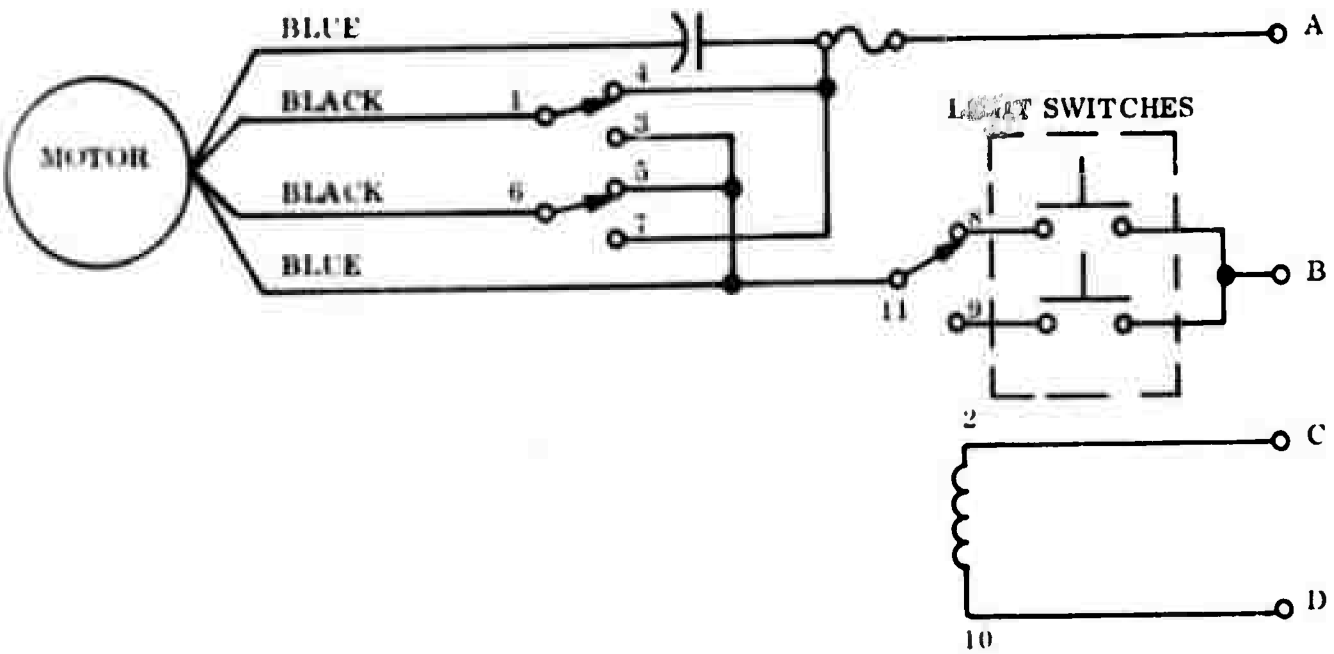


Figure 3-2. Wide Field/Narrow Field Drive Circuit

4.0 TIMING CONSOLE

The timing system used on the Secede II Pointing and Tracking equipment was provided G. F. E. from R. A. D. C. The System consisted of an ASTRO Data Model 6220 Time Code Generator and Model 6222 Universal Tape Search System. The Time Code Generator produced AMR D-5 code which was completely compatible with the D-5 plug-in unit of the Tape Search Unit. Unfortunately, this system produced BCD outputs of time of day in 1 sec. intervals. This time system suffered from two problems. The first was the difficulties involved in sychronizing this timing system to GMT, used throughout the entire Secede experiment and secondly a time resolution of only 1 sec. was considered too coarse to provide beacon position information.

An IRIG-B plug-in unit, Model 6220-903 was therefore purchased and installed in the Tape Search Unit. IRIG-B timing was provided via a land line from a WWV receiver in the BRL Van, also at Site 3. This system provided a visual (NIXI) display of time of day and BCD outputs, to 0.01 seconds. As a backup mode of operation the timing system can be operated open loop through use of the D-5 generator and plug-in unit.

5.0 DATA HANDLING SYSTEM - INTRODUCTION

The Secede II Data Handling System converts all analog signals into a computer compatible digital format for recording by the incrimental digital tape recorder (Kennedy Model 1600 RH/5). The system has the following characteristics:

1. Counts the number of pulses received from each of the Fabry Perot channels and the monitor photometer. On command, the number of pulse in each source will be read out in digital format and in parallel as analog voltages. Input pulse width 0.1

to 0. 5 sec., spaced at least one microsecond apart.

2. The command pulse mentioned above is designated as the channel advance pulse and will occur at a rate of either 10 or 20 Hz. normally 10 Hz.

3. Monitor ninety-one (91) points each time the channel advanced pulse appears, and output data in a digital format.

4. Digital output signals (T^2L) compatible with Kennedy Digital Recorder Model 1600, RH/5, on six parallel lines.

5. Digital writing rate, 250 to 500 Hz.

6. Other input/output signals such as filter position, switch positions, elevation and azimuth angles and timing, are monitored in each framing interval.

7. All signals are compatible with transistor-transistor logic (T^2 L).

   (1) A seventeen(17) bit counter and sto ,e register is used to count pulses for each of three channels.

   (2) The analog voltage readout shall be a ten (10) bit D/A converter with an eight (8) position switch to select the proper readout range.

   (3) Digital readout format per Table 5-1, Data Tape Word Packing.

5.1 Data Tape Word Packing

A data block consists of 144 bits which is an even multiple of 36 (For IBM 7094 and GE 635 computer) and is also even multiple of 16 (For 360 Computer).

The tape format is standard 7 track 6 bit characters and parity (Track C).

TABLE 5-1 IBM TRACK ASSIGNMENTS

Character	1	2	4	8	A	B	C	
1	MI_8	MX_1	MX_2	MX_1	O	O	P	
2	SX_1	SX_2	SX_1	MI_1	MI_2	MI_4	P	Time - BCD
3	ST_4	ST_8	SI_1	SI_2	SI_4	SI_8	P	
4	SH_1	SH_2	SH_4	SH_8	ST_1	ST_2	P	
5	$F1_6$	$F1_5$	$F1_4$	$F1_3$	$F1_2$	$F1_{MSB}$	P	
6	$F1_{12}$	$F1_{11}$	$F1_{10}$	$F1_9$	$F1_8$	$F1_7$	P	
7	$F2_{MSB}$	$F1_{LSB}$	$F1_{16}$	$F1_{15}$	$F1_{14}$	$F1_{13}$	P	
8	$F2_7$	$F2_6$	$F2_5$	$F2_4$	$F2_3$	$F2_2$	P	
9	$F2_{13}$	$F2_{12}$	$F2_{11}$	$F2_{10}$	$F2_9$	$F2_8$	P	
10	M_2	M_{MSB}	$F2_{LSB}$	$F2_{16}$	$F2_{15}$	$F2_{14}$	P	
11	M_8	M_7	M_6	M_5	M_4	M_3	P	
12	M_{14}	M_{13}	M_{12}	M_{11}	M_{10}	M_9	P	
13	D_3	D_2	D_{MSB}	M_{LSB}	M_{16}	M_{15}	P	
14	D_9	D_8	D_7	D_6	D_5	D_4	P	
15	MF_3	MF_2	MF_1	D_{LSB}	D_{11}	D_{10}	P	
16	AX_1	AX_2	AX_4	AX_8	AC_1	AC_2	P	
17	AT_4	AT_8	AI_1	AI_2	AI_4	AI_8	P	Azimuth Angle
18	AH_1	AH_2	AH_4	AH_8	AT_1	AT_2	P	
19	EX_1	EX_2	EX_4	EX_8	EC_1	EC_2	P	
20	ET_4	ET_8	EI_1	EI_2	EI_4	EI_8	P	Elevation Angle
21	EH_1	EH_2	EH_4	EH_8	ET_1	ET_2	P	
22	EV_6	EV_5	EV_4	EV_3	EV_2	EV_1	P	
23	R_1	R_2	R_3	EV_9	EV_8	EV_7	P	
24	$FF2_1$	$FF2_2$	FH_1	$FF1_2$	TF_1	TF_2	P	

MX = Minutes - Tens 0-6

MI = Minutes - Units 0-9

SX = Seconds - Tens 0-6

SI = Seconds - Units 0-9

ST = Seconds - Tenths 0-9

SH = Seconds - Hundredths 0-9

F1 = Fabret-Perot Channel One 17 Bits

F2 = Fabret-Perot Channel Two 17 Bits

M = Fabret-Perot Monitor 17 Bits

D = Digital Voltmeter 12 Bits

MF = Monitor Filter 3 bits

AC = Degrees - Hundreds 0-3
AX = Degrees - Tens 0-9
AI = Degrees - Units 0-9
AT = Degrees - Tenths 0-9
AH = Degrees-Hundredths 0-9

EV = Event Indicators 9 Bits Total

R = Channel Advance Rate

FF1,2 = Fabret-Perot Filters Channel 1 & 2

Event Designations

EV-1	K1 & K2 Generator	J3-u	Tracking
EV-2	K1 & K2 Generator	J3-Y	Position
EV-3	WF/NF Switch	14-B	
EV-4	K1 & K2 Generator	J3-H	Scan Type
EV-5	K1 & K2 Generator	J3-J	
EV-6	K1 & K2 Generator	J1-T	NIKON
EV-7	K1 & K2 Generator	J3-P	I. O. Filter
EV-8	K1 & K2 Generator	J3-R	Position
EV-9	Calibrate Switch	15-B	

5.2 System Design - Data Handling System

The data handling system design resulted in the block diagram shown in Figure 5-1, "The Data Handling System Block Diagram". Refer to the schematics and interconnection diagrams of the Data Handling System for the detailed design. Each block shown in the schematic is a functional printed circuit card. Maximum use of the standard SN7400 (T^2L) integrated circuits has been used throughout the design. The data handling system; also called the recording system, has been packaged in two nineteen inch cans that are mounted in the control console. One can contains twelve cards, the other has eleven. Actually only eight cards were required for the second rack, except that the IRIG time code generator and azimuth/elevation readouts were negative logic and high voltage logic (12 v), respectively. Two additional cards were necessary to incorporate the necessary circuit change to make these signals compatible with T^2L circuitry.

The breakdown of the functional circuits packaging was to minimize the number of interconnecting wires between mounting racks. One mounting rack contained the three, seventeen bit counters and storage registers, three D/A converters with their D/A logic circuits, the corresponding shift register readout circuits and the counter/register logic circuits. The second mounting rack contained the tape control logic circuits, the shift register readout logic, four shift register readout cards to monitor the ninety-six points, also two summing logic cards. The modification required two level translator cards to change from negative to positive logic.

A block diagram of the counter/register logic card is shown in Figure 5-2, "Counter/Relay Logic". The clock advance pulse (command pulse) is the signal to record all data into shift registers for readout to the digital recorder and analog print out. The

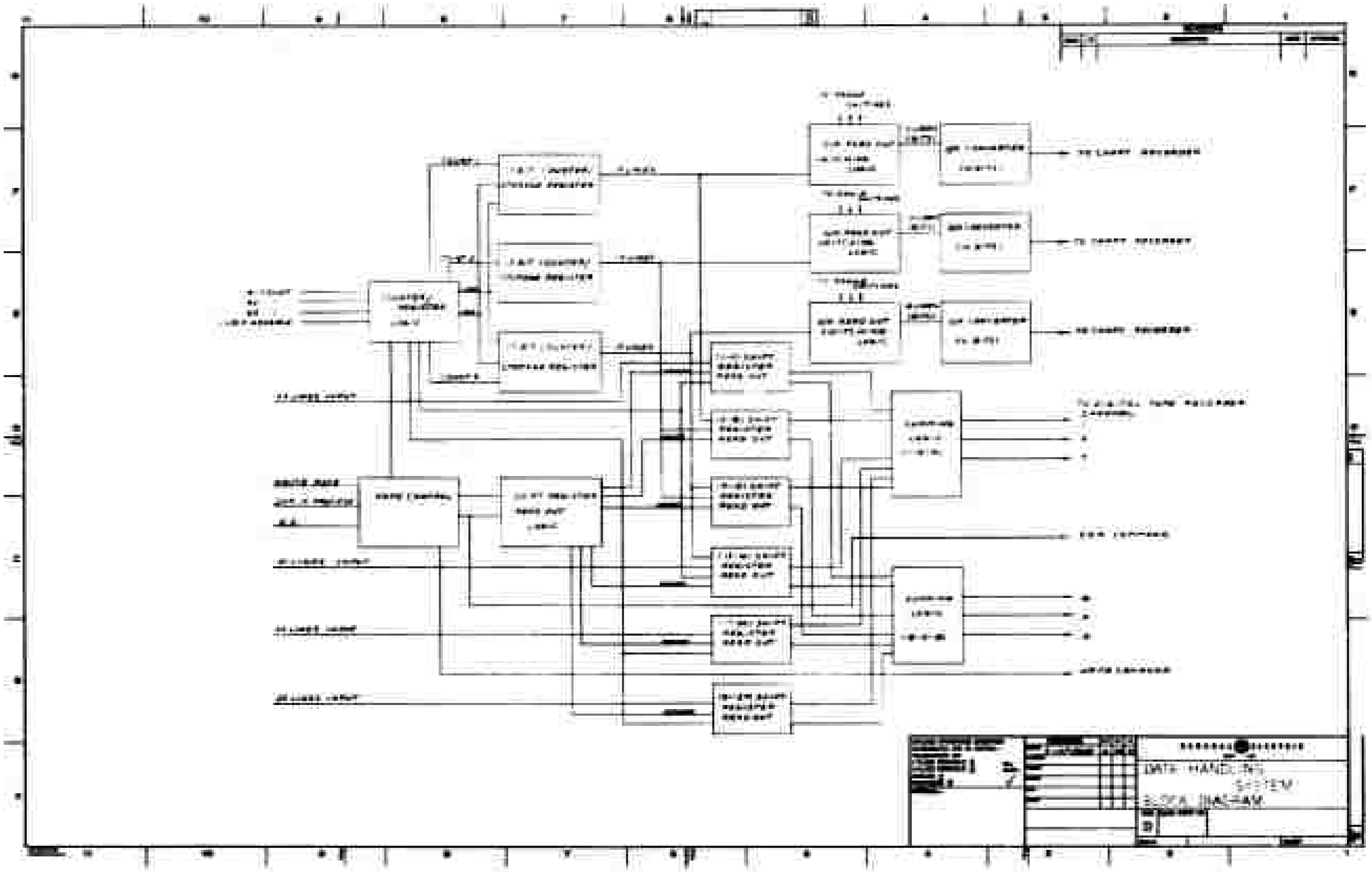


Figure 5-1. The Data Handling System Block Diagram

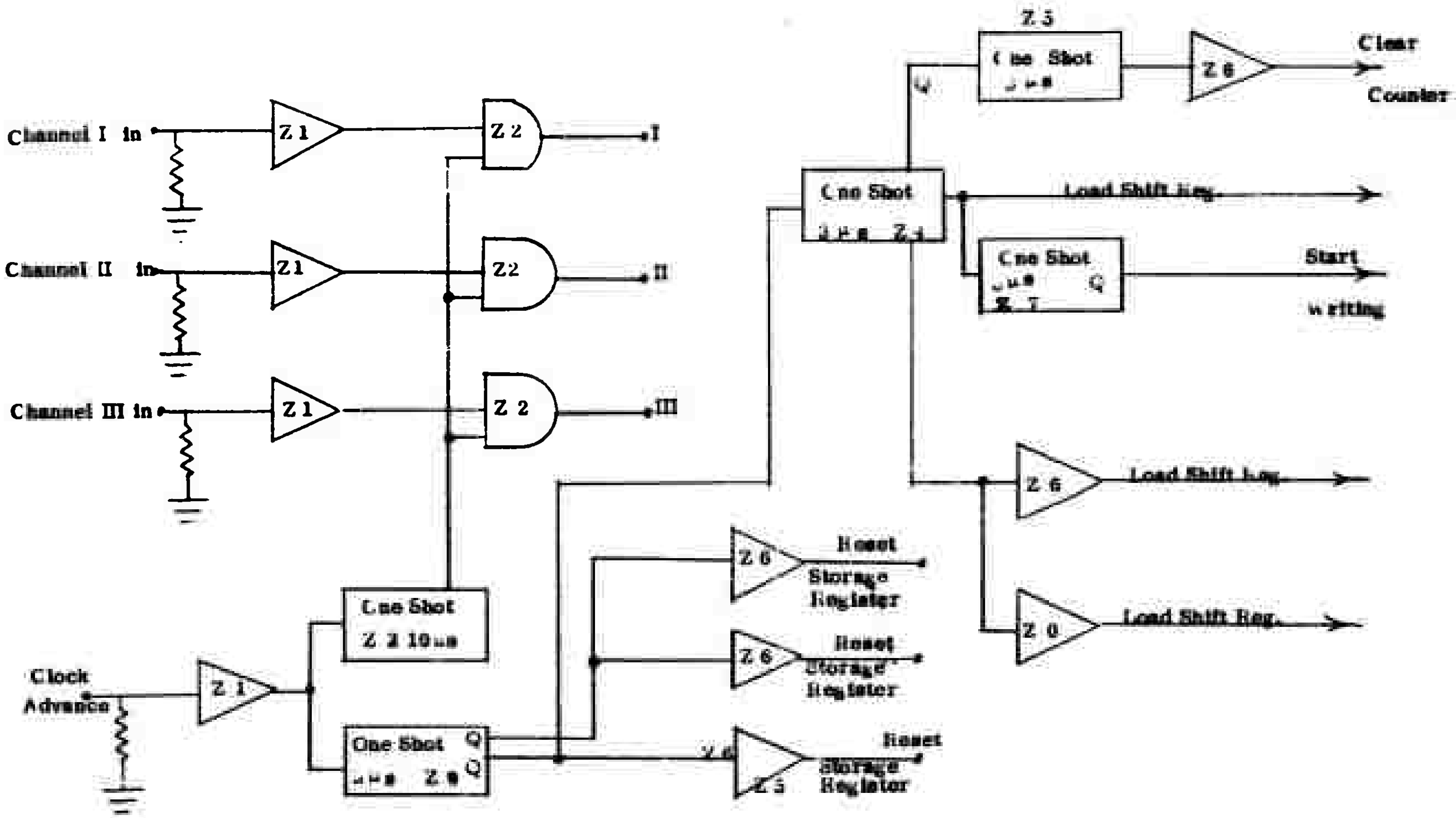


Figure 5-2. Counter/Relay Logic

clock advance pulse triggers the 10μsec one shot multivibrator Z3 to stop all pulses from entering the three channel counters. The clock advance pulse also triggers a 3μsec one shot multivibrator (Z8) to generate the storage register reset pulse. The Z8 one shot then triggers a (Z4) one shot multivibrator which generates the load shift register pulse, 3μ sec wide. All monitoring points and data (142 in all) are placed in their corresponding shift register positions. The (Z4) out, t then triggers another 3μ sec one shot multivibrator (Z5) to generate the clear counter pulse, and trigger (Z7) one shot multivibrator to generate the 30 μsec start writing pulse for the tape control logic. The counters are gated off during the time the reset, clear counter and load shift register pulses are generated.

In the SN 7496 shift registers (5 bit) units, it was necessary to reset the shift registers to zero before loading them with zeros or ones. Normal parallel in/parallel out shift registers would not require the reset before load function. It was a simple modification to only add one additional one shot multivibrator. The counter/register logic card supplies all the necessary signals (pulses) to get the data into the storage (shift) registers.

All three Fabry Perot and photometer channels are identical. Each 17 bit counter/storage register card contains a 17 bit counter and a 17 bit storage registers the pulses are counted in the counter, on command, the count is inhibited, shift register reset and then the digital number is transfered to the 17 bit shift register from the counter. The 17 bit shift register keeps its digital number until the next command pulse appears.

During commands, the shift register digital number is processed to the digital recorder and also fed into a D/A converter to obtain an equivalent analog output voltage.

To obtain the analog voltage proportional to the number of pulses in the 17 bit shift register, a D/A converter is required. Since the accuracy of the brush recorder is approximately 3%, an 8 bit D/A converter was supposedly adequate for accuracy requirements. Figure 5-3 "D/A Readout Switching Logic Block Diagram" illustrates the use of a 10 bit D/A converter with ten static multiplexers to cover the complete range of readout in eight steps. The binary numbers from 1 to 8 are fed in on A, B, C to select the proper range of D/A conversion. A, B, C inputs are zeroes and ones from the range (manual) selector switch on the console. The switch is marked from 2^{10} to 2^{17} indicating the highest number of pulses within the shift register. This allows selection of coarse or fine selections of the analog voltage resolution capability. The D/A output voltage range is from 0 to -10 v DC. The inputs the SN74151 multiplexers indicate the shift register bit numbers, from 1 to 17.

The 17 bit shift register readings must be recorded on digital tape. The digital recorder has six channels and 142 data points must be monitored, therefore, four readings are required to record the 142 points. Six readout cards were designed into the system and each readout card would store 24 monitoring points. The first 24 monitoring points covered the IRIG timing. The next 51 points were alloted to the three channels of 17 bit shift registers. Two of the readout cards (48 data points) were placed in the same rack with three channels of 17 bit counters, shift registers, D/A converters etc. These readout cards differed from the other readout cards

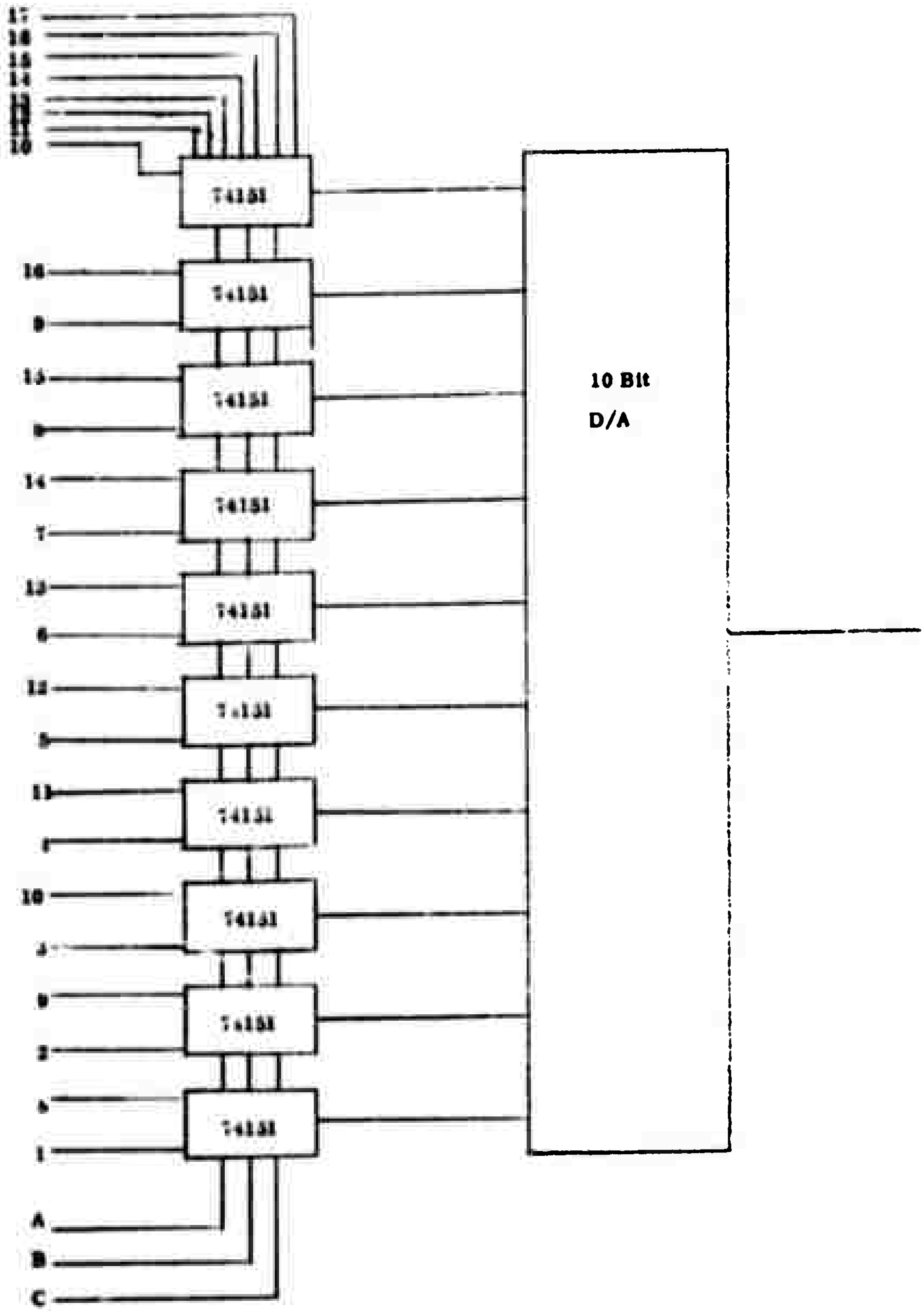


Figure 5-3. D/A Readout with Switching Logic

because they did not contain any storage registers. Since storage registers already existed on the 17 bit counter/storage register cards, only the six channel multiplexers were needed for the readout function.

The readout cards took the 24 inputs and converted to four groups of six readings, the six readings for the six channel digital recorder. The shift register readout logic cards, is the second card rack, supplied the necessary shift pulses (writing rate) to sequence the readings properly. The readout sequence of the cards are (1-4), (5-8), (9-12), (13-16), (17-20), (21-24), only one card is readout at any one time and each card supplied four sets of six readings . The block diagram and the system interconnection diagram and schematics indicate the proper monitoring points and sequence.

The second mounting rack contains the tape control circuits, readout logic circuits, four readout cards (with storage registers) and the summing circuits. The level translations I and II were later added to properly format the IRIG timing signals from negative logic to positive logic.

The tape control circuits interfaces the command signals and digital recorder signals with the data handling system for proper recording of the digital handling system for proper recording of the digital monitoring data signals. The start writing pulse is obtained from University of Pittsburgh equipment to start recording (refer to tape control sechmatic). If the tape recorder is ready, the gap in process signal will be low; zero volts, allowing the writing rate pulses to pass through the gate Z1 pin 3. If the recorder is not ready, the gap in process signal will be high, +5v, and

the writing rate pulses are inhibited until the recorder is ready. When the writing rate pulses (250 - 500 Hz) pass through gate Z1 pin 3, they feed into a counter (Z7 and Z8) that counts to twenty-four. After twenty-four pulses are counted, the one shot (Z10) is triggered, this triggers a R/S flip-flop (Z9) to inhibit the writing rate pulses until the next start writing pulse appears. In addition, the output of gate Z1 pin 3 (at the writing rate) triggers a one shot multivibrator (Z2) (75 μ sec), these pulses are designated write command and are fed directly to the digital recorder. The output of Z2 triggers another one shot (Z3) to generate a 12 μ sec shift pulse, at the writing rate. The shift pulse occurs after the write command pulses, this is to allow the storage register logic circuits to settle down before the write command pulse directs the recorder to record the signal. The tape control unit also receives an end of instruction (EI) signal from University of Pittsburgh equipment. If the data handling system is recording data when the (EI) pulse appears, it will complete that set of 24 readings and then stop. When the readings are completed a one shot multivibrator (Z5) (2 millisecs) is triggered and then a second one shot (Z6) is triggered to generate a 50 μ sec end of record (EOR) command signal to the digital tape recorder.

The shift pulses from the tape control card pass to the shift register readout logic card. Refer to schematic, the shift pulses pass through an inverter Z1 and into a dual flip-flop Z2. The Z2 flip-flop have four logic counts, these counts appear on A & B via Z6 inverter, a nd will be used for gating the multiplexers on all six readout cards. The output of the dual flip flop (Z2) fed a divide by six counter (Z3). The decoder (Z4) has six outputs only one output is low at any one time. They decoded output will sequence in the proper order,

pin 1, 2, 3, 5, 6, and then 7. These outputs are inverted via (Z5) and applied as a strobe pulse on the readout card. The combination of the strobe pulse and the A & B signal, will properly sequence the readings of all six readout cards. Eash readout card will have six outputs, designated 1, 2, 4, 8, A and B. All six outputs are fed to the summer circuits. The flip flop (Z2) and counter Z3 are reset with tape control reset pulse to properly phase Z2 and Z3.with the counter (Z7 and Z8) on the tape control cards.

The summer circuits were broken down into two cards, One card contains 1, 2, 4 channels and the other has the 8, A and B channels. Each readout card has six outputs, three outputs go to each summer cards. These signals are OR'd together (using Z1 and Z4, Z2 and Z5, Z3 and Z6) on the summer card providing three output channels for the digital tape recorder.

The level translator card contains two amplifiers for each input. The first transistor (2N2957) converts the negative logic to a positive logic signal and the second inverter (7404) is required for proper format in T^2L and to make negative "one" be a positive "one".

6.0 RECORDING CONSOLE

The recording console is an upright 7 foot rack which houses a digital tape recorder, Fabry Perot interferometer controls, an analog chart recorder, the cross over and demodulator chassis and two servo power supplies. The operator stationed at this console controls all Fabry Perot and photomultiplier functions and monitors analog outputs during mission coverage. It is physically located to the right of the master control console. Coordination between the two operators of each of the consoles is required to ensure maximum data coverage. This is necessary for example to prevent spatial scanning during the time in which a wave length scan is being taken. It is also necessary when changing from a wave length scan mode to a spatial scan mode that the scan be "enabled" prior to the interferometer reaching a pressure value corresponding to the hyper fine peak. Several dry runs were found to be quite useful prior to actual mission coverage.

The following few pages list the various interconnections within the control console proper.

For detailed schematics of the Kepco Model EOP 72-5M amplifier and the Kennedy Model 1600 RH5 digital tape recorder see the appropriate operations and service manuals.

<u>RECORDING CONSOLE</u>

<u>INTERCONNECTIONS</u>

J-RC-2 <u>PT 02SE-20-39P</u>			Kennedy Type <u>Amphenol 57-30360</u>
Analog Ch. 2	a	TB-RC-9-1	
	E	2	
	NC	3 Shield	
Analog Ch. 1	b	4	
	c	5	
	NC	6 Shield	
Analog Ch. 3	F	7	
	G	8	
	NC	9 Shield	
+5 VDC	Z	10	
	M	11	
	NC	12 Shield	
Gnd	D	13	11, 29, 6, 7
	N	14	36, 8
	d	TB-RC-10-1	
	J	2	
	NC	3 Shield	
	P	4	
	e	5	
	NC	6 Shield	
D.D. 1	i	7	10
2	u	8	19
4	i	9	17
8	T	10	20
A	C	11	21
B	K	12	16
Write step	Y	13	14
EOR	B	14	30
GAP		TB-RC-7-1	28

RECORDING CONSOLE INTERCONNECTIONS

J-RC-1 PTO2SE-22-55S		TB-RC-7
A	Gap in Process	1
G	Write/Rate/Step	2
s	EOR/I	3
t		4
N		5
D	FF1, F.P. Filters	6
X	$FF1_2$	7
C	$FF2_1$	8
V	$FF2_2$	9
b	TF1 Monitor P+	10
c	MF_1 Monitor Filters	11
p	MF_2	12
p	MF_3	13
q	TF 2 Monitor Pt	14
		TB-RC-8
X	R_1 Channel Advance Rate	1
B	R_2 Channel Advance Rate	2
Y	R_3 Channel Advance Rate	3
h	Channel Advance	4
y	SS. ON/OFF	5
i	S ON/OFF	6
EE	K_2 Reset	7
W	D_{MSB}	
U	D_2	
GG	D_3	
FF	D_4	
T	D_5	
BB	D_6	
HH	D_7	

RECORDING CONSOLE (continued)

J-RC-1
PTO2SE-22-55S

u	D_8	
n	D_9	
Z	D_{10}	
k	D_{11}	
CC	D_{LSB}	
Z	Range Switch I	A
F		B
i		C
S	Range Switch II	A
r		B
E		C
9	Range Switch III	A
m		B
a		C
V	Spare	
d	Spare	
H	Spare	
J	Spare	

6.1 CROSSOVER, DEMODULATOR AND COMPENSATION NETWORK

The crossover demodulator circuitry is a part of the control loop for the direction of the Secede II Pedestal. The purpose of the crossover network is to choose between the high resolution and low resolution control transformer error signals. As the pedestal approaches the desired position the error signal from the one speed CT falls below a given value. When this happens control is automatically transferred to the high resolution 36 speed control transformer. The value of this crossover is adjusted such that the 36 speed CT is within one revolution of the desired pointing direction, 10 degrees.

The AC error signals are fed into the demodulation circuitry where it is synchronously demodulated and appears as a bipolar output of the LM 308 amplifier. (See crossover demodulator and compensation network schematic in Figure 6-1.) This output is fed into the compensation network consisting of a 40J amplifier with appropriate feedback and tackometer input signals. The appropriate values of feedback resistors capacitors and tackometer input circuitry are shown on the schematic. These values were derived during the measurements of the mount dynamics. A discussion of the test performed in the definition of these components is given in the Section 8.2.

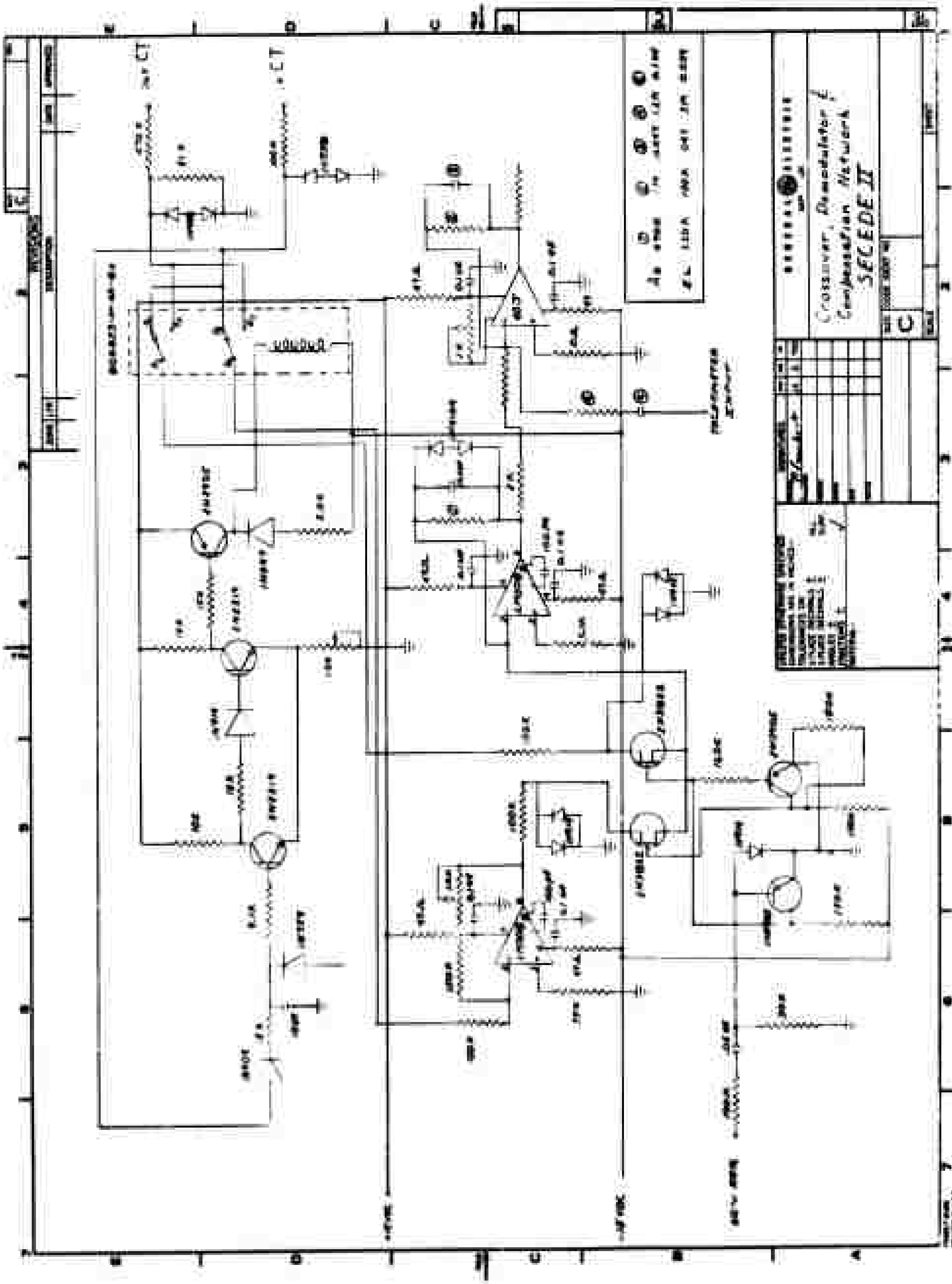


Figure 6-1. Crossover Demodulator and Compensation Network Schematic

RECORDING CONSOLE

INTERCONNECTIONS

CROSSOVER AND DEMODULATOR

Digital Readout J1 El	J-RC-8 PTO2P -14-18S	J-RC-4 PTO2SE -18-32P	J-RC-3 PTO2SE -18-32S	TB-RC -4	Function
M	P	V	V	1	S2
N	C	f	f	2	S1
L	E	U	U	3	S3
R	F	S	(S to crossover)	4	R2
K	B	e	(e to crossover)	5	R1
C	U	d	d	6	S1
B	S	B	B	7	S2
A	N	C	(C to demod.)	8	S3
		D	(D to demod.)	9	R1
51 A		W	W	10	R2
K	K	X	(X to crossover)	TB-RC-5-1	R1
R	M	F	(F to crossover)	2	R2
N	J	g	g	3	S1
M	G	P	P	4	S2
L	T	j	j	5	S3
		c	(c to demod.)	7	R2
C	H	N	(N to demod.)	7	R2
B	R	L	L	8	S1
A	D	b	b	9	S2
		h	h	10	S3

RECORDING CONSOLE

INTERCONNECTIONS

CROSSOVER AND DEMODULATOR

J-RC-6
PT02-SE-20-16S

A	Az	A1	A
B	Az	A1	B
C	Az	A2	C
D	Az	A2	D
E	E1	A1	E
F	E1	A1	F
G	E1	A2	G
H	E1	A2	H
J	115	Hot	
K		Hot	
L		Hot	
M	115	Cold	
N		Cold	
P		Cold	
R		Chassis	
S N. C.			

ERROR SIGNALS

J-RC-9 PT02P-8-4S		TB-RC-6
A	Az Error	1
B	Ret	2
C	E1 Error	3
D	Ret	4

RECORDING CONSOLE

INTERCONNECTIONS

CROSSOVER AND DEMODULATOR

TB-RC-6

1. Az Error
2. Az Error Ret
3. Elevation Error
4. Elevation Ret.
5. TB-RC-4-10 and TB-RC-4-4
6. TB-RC-5-7 and TB-RC-5-2
7. Cold 115 VAC
8. TB-RC-5-6 and TB-RC-5-1
9. TB-RC-4-9 and TB-RC-4-5
10. Hot 115 VAC

7.0 SCAN COMPUTER

The Scan Computer is an analog device which can be programmed in real time to cause the main pedestal to perform a linear or raster scan of the far field.

The geometrical coordinates are shown in Figure 7-1. The center of the sphere is the position of the main pedestal. θ and ϕ are the declination and azimuth angles respectively. σ is the angle between the apparent vertical on the television monitor and is perpendicular to the direction of scan.

The scan computer consists of three sets of instrument servos (motor driven potentiometers). The first pair follow the precision potentiometers in the manual sighting station or can be driven to a selectable position by use of the velocity joystick. Provisions have been made to direct the first two instrument servos from external signals, however, these signals must have the same characteristics as those of the manual sighting station. This mode of operation was provided so that the pedestal could be directed remotely from a remote radar site, but was never implemented.

The second pair of instrument servos computes the starting point of each line in a raster scan. The following set of equations are calculated:

$$\text{Cos}\ \theta_n = \text{Cos}\ \theta_o - K_1 t\ \text{Cos}\ \sigma\ \text{Sin}\ \theta_o$$

$$(\phi_n - \phi_o)\ \text{Sin}\ \phi_n = K_1 t\ \ \text{Sin}\ \sigma$$

where θ_n = line starting point in elevation

ϕ_n = line starting point in azimuth

ϕ_o, θ_o = initial coordinates at time $t = 0$

t = time

σ = scan angle

K_1 = "vertical" rate of raster.

SECEDE II

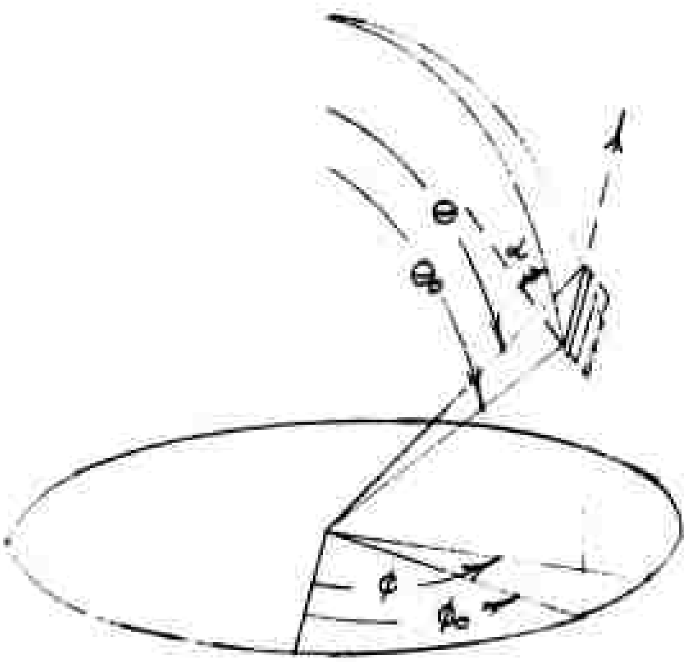


Figure 7-1. Scanning Geometry

Each of these angles θ_n & ϕ_n is computed continuously but, is executed only at the end of each linear scan within the raster. θ_n & ϕ_n therefore assume discrete values at the beginning of each line.

The last pair of instrument servos compute the appropriate positions of θ and ϕ for time t. These instrument servos each turn a set of 1x and 36x control transformers which direct the main pedestal. In addition, each has a low resolution potentiometer which provide a linear voltage which is proportional to the position of θ and ϕ. The following set of equations is computed:

$$\text{Cos}\ \theta = \text{Cos}\ \theta_n + K_2 t \quad \text{Sin}\ \alpha\ \text{Sin}\ \theta_n$$

$$(\phi - \phi_n)\ \text{Sin}\ \theta = K_2 t\ \ \text{Cos}\ \alpha\ - 1/2\ (K_2\ \ )^2\ \text{Cos}\ \theta_n$$

where θ = elevation angle at time t

ϕ = azimuth angle at time t

K_2 = "horizontal" raster rate

A complete schematic of the scan computer is shown in Figure 7-2. To achieve the desired accuracy, buffer amplifiers from each of the potentiometers have been employed. In most cases the LM308 amplifier was employed where simple signal inversion was necessary. When a summing amplifier was necessary the 40J was employed, due to its better zero offset and thermal characteristics.

An error analysis was performed on the system in which it was assumed that the major source of error was due to the conformity of the potentiometers to the desired theoretical function. A computer program was written in which the percent conformity could be separately varied for each of the potentiometers. A simple RMS addition of all the error sources was employed. The results are shown in Figure 7-3. It should be noted that $\pm$ 2 mr was the design goal, however, with state-of-the-art potentiometer they could not be achieved over the entire range of operation through the entire scan computer system.

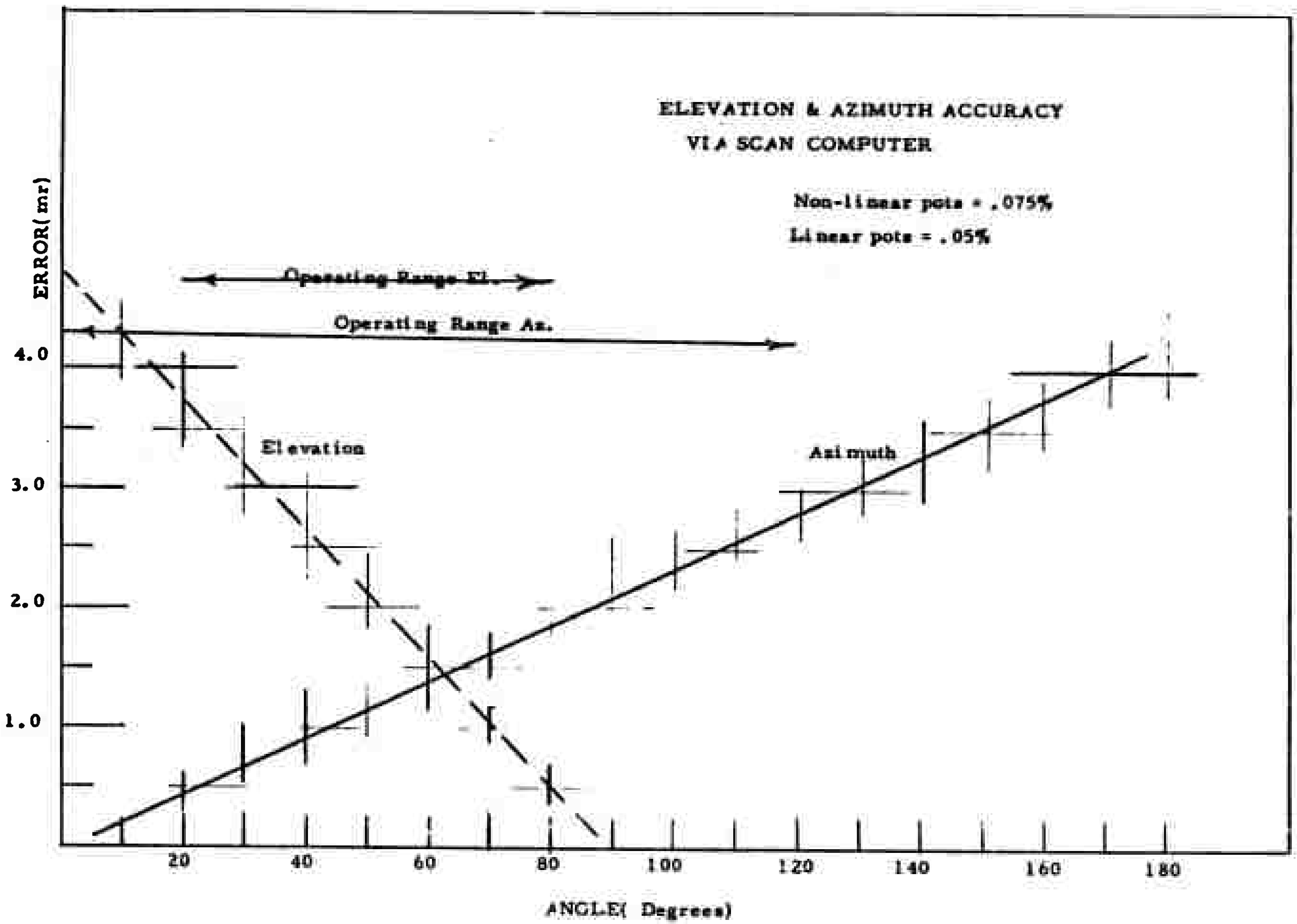
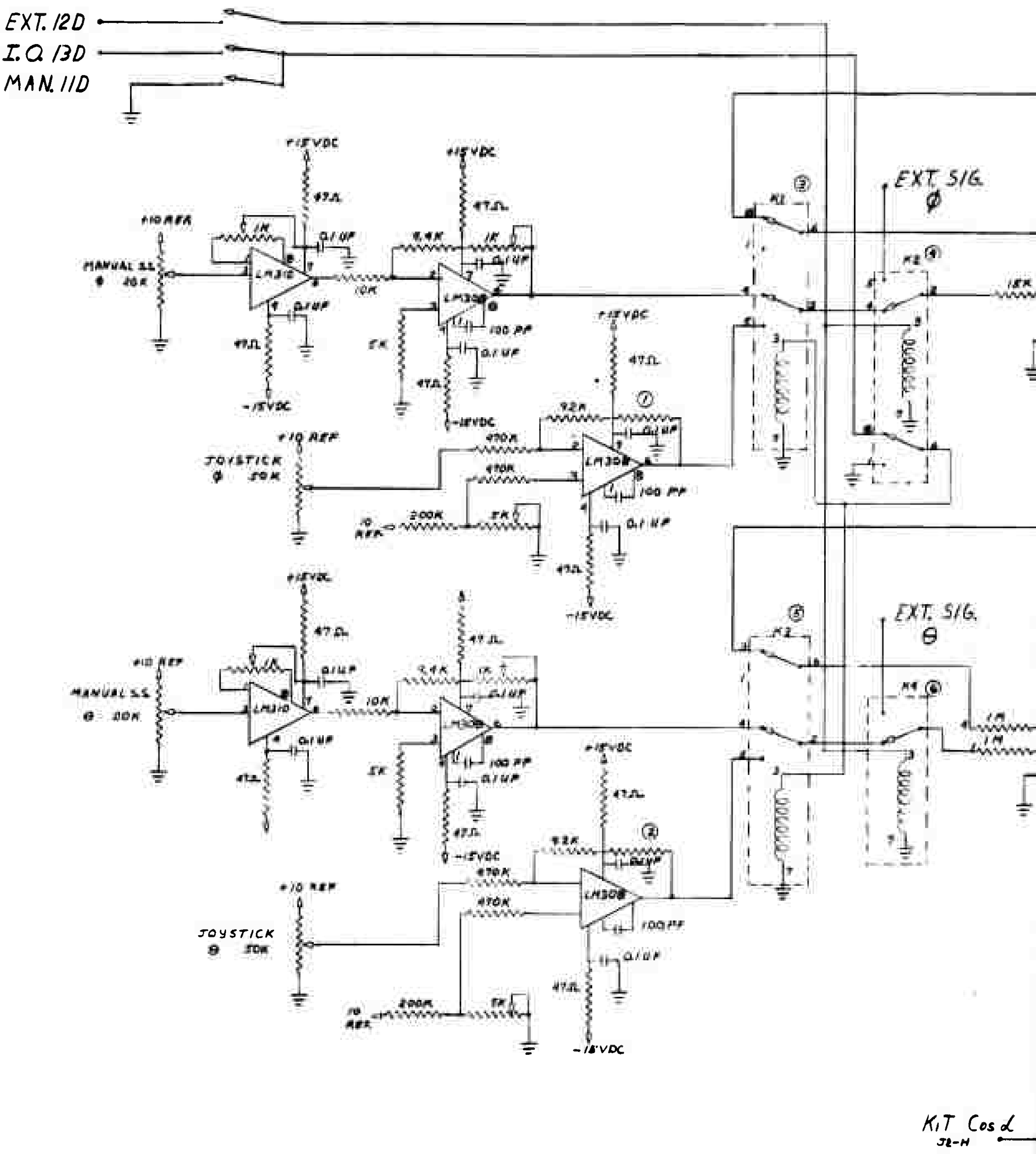
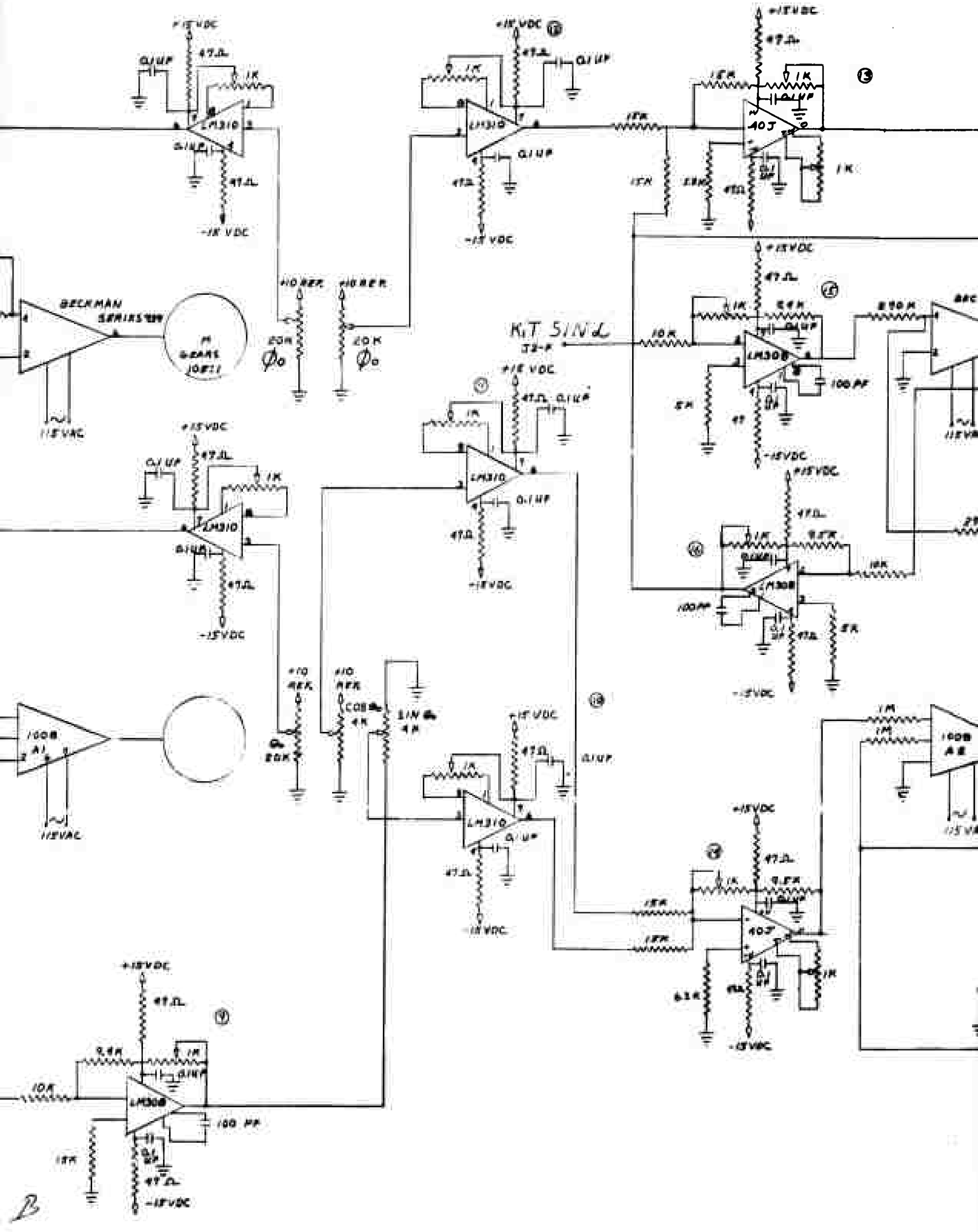


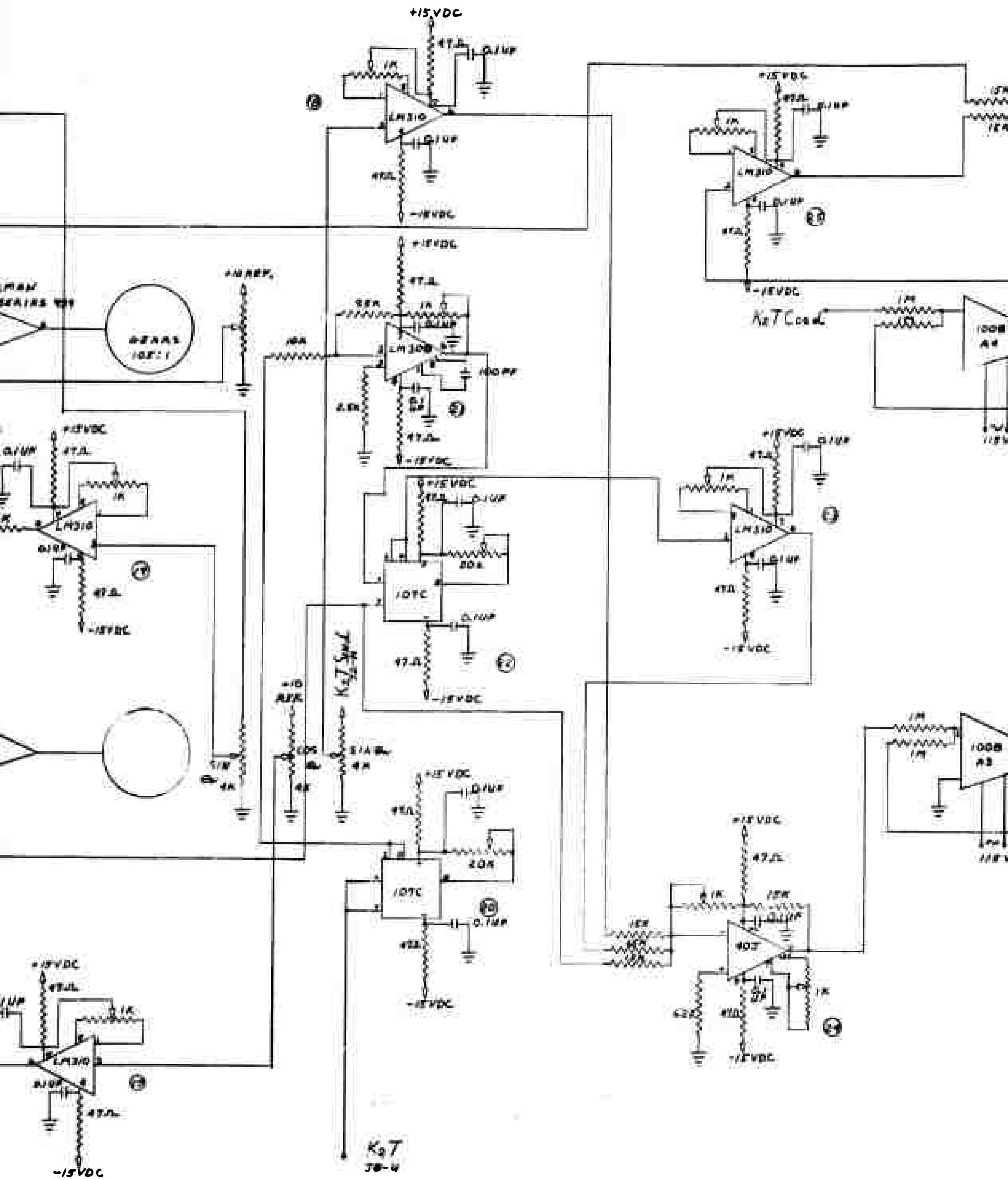
Figure 7-3. Elevation and Azimuth Accuracy via Scan Computer



EXT. 12D
I.Q 13D
MAN. 11D
+15VDC
47Ω
+10 REF
MANUAL S.S.
φ 20K
1K
0.1 UF
LM310
10K
8.4K
LM308
100 PF
5K
-15VDC
92K
470K
JOYSTICK
φ 50K
200K
10 REF
K1
K2
EXT. SIG.
φ
K3
K4
EXT. SIG.
θ
MANUAL S.S.
θ 20K
JOYSTICK
θ 50K
1M
KiT Cos α
J2-H



+15VDC
47Ω
0.1UF
1K
LM310
-15VDC
BECKMAN
SERIES 939
M
GEARS
10E:1
115VAC
+10 REF
20K
ϕ_0
40J
15K
KiT SIN L
J2-F
10K
LM308
100PF
5K
9.5K
100B
A1
COS θ_0
4K
SIN θ_0
θ_0
20K
1M
A8
9.4K
100 PF
6.1K


+15VDC
-15VDC
47Ω
0.1UF
1K
LM310
LM308
107C
20K
10K
2.5K
100PF
GEARS
105:1
+10 REF.
1M
100B
K2T
J8-4
15K

c

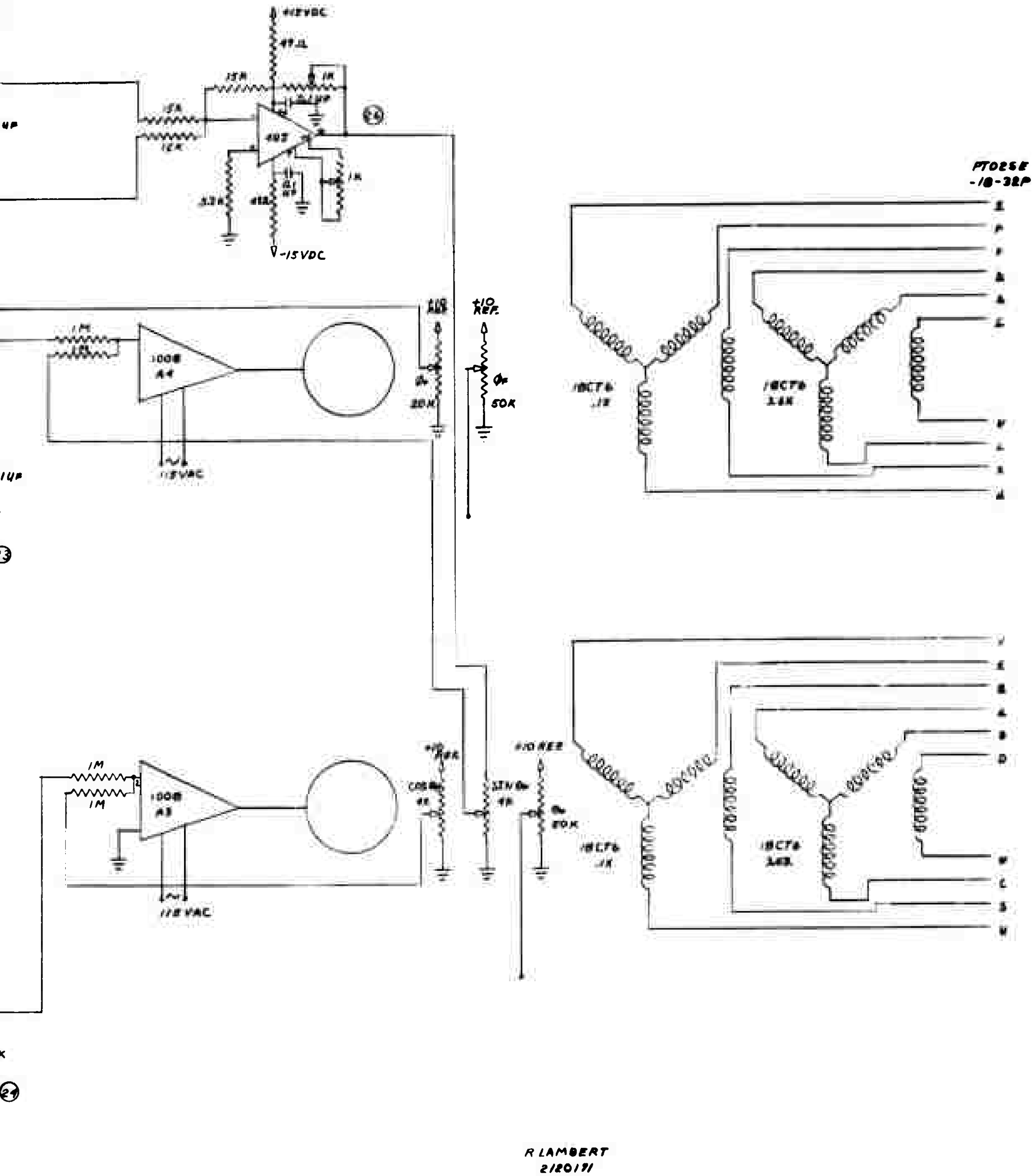


Figure 7-2. Scan Computer

D

To meet specification of directing the main pedestal to ± 2 mr an additional set of control transformers were placed in the manual sighting station. Test at the General Electric Company showed a reproducibility of ± 1 mr can be achieved by approaching a given spot from the same direction each time. Gear backlash however produced an error of approximately 10 mr when a point is approached from opposite directions.

7.1 Scan Rate Generator

The Kt generator has been designed to generate two linear (staircase) sawtooths. The basic requirements of the sawtooths were as follows:

(1) Linear sawtooth to scan a mount twenty (20) degrees, in azimuth (K_1t) and (K_2t).

(2) Scanning rates of 0.4 to 40 milliradians per second. Include a x1 and x10 control. This reflects into a 0.4 to 4 milliradian per second and a 4 to 40 milliradian per second range. Each range shall be divided into nineteen discrete scan rates and the twentieth position shall be a zero scan rate.

(3) The sawtooth amplitude shall be variable, manually adjustable.

(4) The K_2t generator shall scan normally with its flyback. The K_1t generator shall be updated during the flyback of the K_2t generator. This results in a linear scan of K_2t generator and a step scan of the K_1t generator.

(5) Provision shall be made to step scan, return scans to zero volts.

(6) Selectable scans

(a) Linear Scan (K_2t generator scan only)

(b) Raster Scan (Both K_1t and K_2t generator scanning)

(c) Radar Scan (de-energize K_1t & K_2t generator and allow external radar generate its own scan)

(d) Single Scan and Multi-Scan. The single scan allows only one scan of either linear or raster scan. Multi-scan is a continuous scan of the linear or raster mode.

(7) In single scan mode, return scan to zero and causes the STOP switch to flash.

(8) Flyback periods of mount shall be two seconds and four seconds. The flyback period shall be two seconds for sweep amplitude of less than ten degrees and four seconds for sweep amplitudes greater than ten degrees.

The limits of the sca. ~ates, linearity requirements and the step-scan of (K_1t), dictated the use of a digital des... approach.

Figure 7-4 is a block (functional) diagram of the K_1t and K_2t generators. The K_1t generator consists of three printed circuit cards and the K_2t generator consists of three printed circuit cards. Maximum use of the SN7400 series Transistor-Transistor Logic (T^2L) has been followed. The master oscillator along with some buffer amplifiers has been placed on a separate card.

Referring to the schematics and interconnection diagrams for the Kt generator unit, the unit consists of a housing with ten printed circuit cards, the seven cards mentioned above and two logic cards to convert the control panel switch positions to digital logic required for the data handling system. The tenth card is a television boresight generator. It generates a pulse (adjustable) to indicate the center of the television camera field-of-view.

Refer to the individual card schematics for the "Z" numbers shown in Figure 7-4. For example, the K_1t generator appears on the K_1t logic, K_1t counter cards and the K_1t D/A converter. The K_2t generator appears on the K_2t logic, K_2t counter cards and the K_2t D/A converter. Let us follow the K_2t generator signal flow, it is used in the normal scanning mode, whereas, the K_1t generator functions in step scan mode.

A 13.7 KHz oscillator, free running multivibrator with self starting circuit, generates the master clock, designated M.O. in Figure 7-4 Z1A input of the K_2t logic card. Z1A is a four-input NAND gate that can stop the clock pulses from passing to the range selector circuit. If the K_2t scan rate (20 position switch) is a zero function, then the output of Z6 is low and keeps Z1A pin 2 low and blocks the clock pulses from passing through Z1A. Any other position of K_2t scan rate (20 position switch) will keep Z1A pin 2 high, open gate. Z1A pin 4 is tied to Z7 pin 2 and essentially to SW1C, SW4C, +5 VDC and stop circuit viz Z1B and Z7. Z1B is also a NAND and brings the additional controls

to Z1A pin 4. When scan switch is in stop position, SWIC is ground (Z1B pin 9) and so is Z1A pin 4, to stop clock pulses from passing through Z1A. When system is in radar scan then Z1B pin 12 is grounded, this also keeps Z1A pin 4 at ground (low) to block clock pulses. When the single scan mode is used, and the stop light is flashing, it keeps Z1B pin 13 at ground and Z1A pin 4 is again grounded to block the clock pulses from reaching the range selector circuit. During the flyback period of the K_1t generator, Z1A pin 5 is held low to block the clock pulses through Z1A.

The output of Z1A is fed into the range selector circuit. This circuit consists of a Z3, Z4, Z5 which is a 10 bit counter, whose actual countdown is controlled by the preset inputs (pins 1, 9, 10 & 15 of Z3 and Z4), via the 20 position scan rate selector switch on the control panel. The preset inputs are kept at 0V or +5V DC, for proper logic control. Z2 has three (2 input) Nand gates that is used as a logic gate to select one of two clock sources. These logic gates are controlled via x1, x10 switch on control panel, either Z2 pin 2 or Z2 pin 9 is held at ground or +5V or vice versa. The two clock sources are the normal output of Z5 pin 9 and the divide by ten output of Z8 pin 11. The frequency of Z5 pin 9 is ten times the frequency of Z8 pin 11.

The output of the range selector circuit is at Z2 pin 11 (J7-W) and passes through an inverter (Z4) on K_2t counter card, to a 12 bit counter, Z1, Z2, Z3 and inverters Z5 and Z6. The 12 bit counter will count to 4096, with the lowest scan rate, 0.4 milliradians per second, (3.4 HZ input to 12 bit counter), the sweep could last for 1175 seconds. Actually, 870 seconds are required to meet maximum amplitude and lowest scan rate. Therefore, the 12 bit counter is large enough. A 12 bit D/A converter was purchased to convert the digital count to an analog voltage. The D/A converter output is a staircase sawtooth going from 0 to +10V in 4096 steps, each

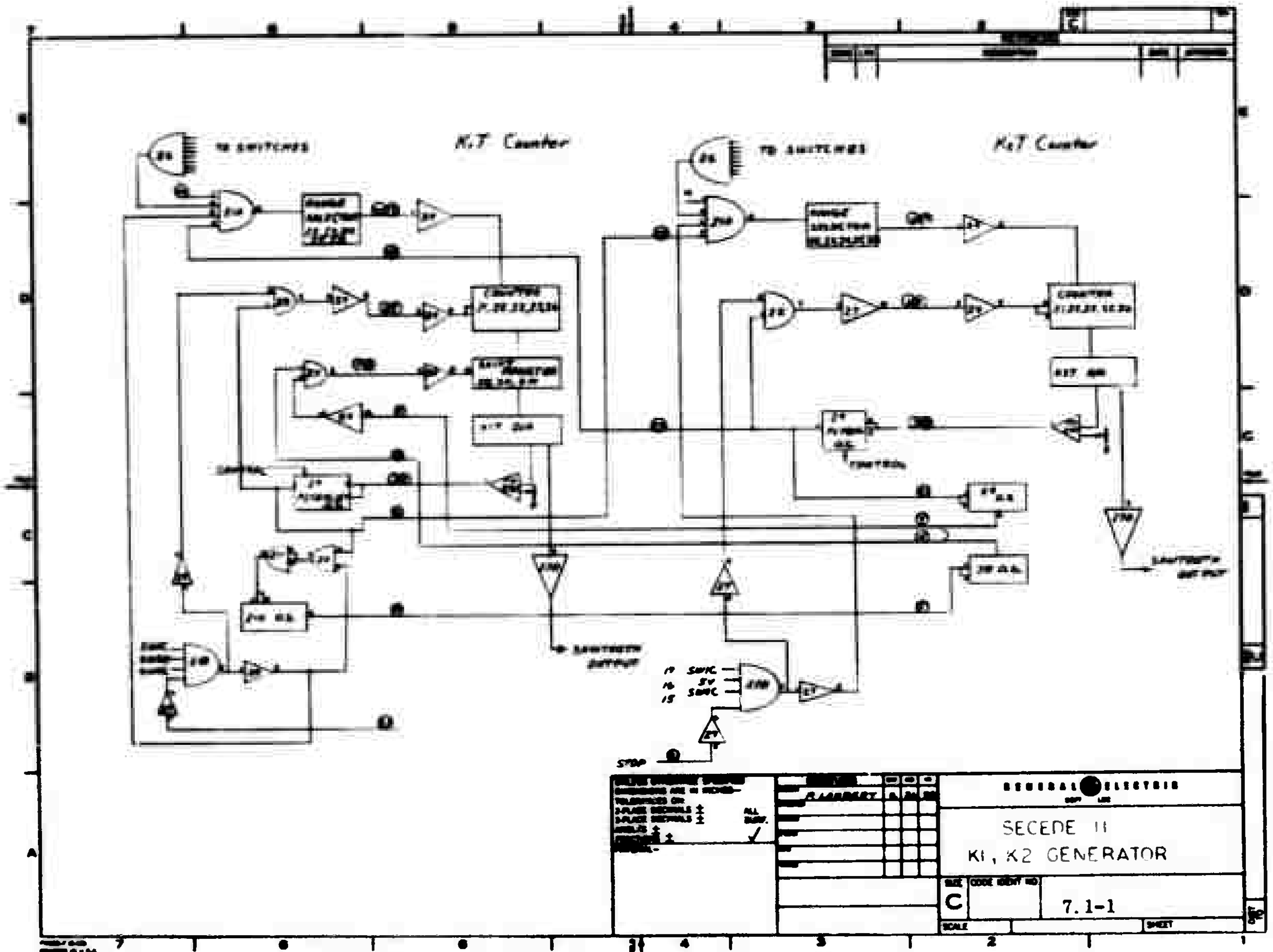


Figure 7-4. K_1T and K_2T Generators

step is approximately 2.5 millivolts.

The D/A converter sawtooth is applied to a threshold detector Z7 and K_2t counter card. The threshold is set by the K_2t amplitude control pot on the control panel. When the sawtooth voltage just exceeds the amplitude control voltage, the threshold detector generates a negative pulse which triggers the flyback one shot miltivibrator Z9 on the K_2t logic card, to generate the K_2t flyback pulse. The K_2t flyback pulse is used to reset the 12 bit K_2t converter to zero and returns the sawtooth to zero volts. The flyback pulse passes through Z2 NAND gate. The NAND Gate Z2 is also used to reset the counter when the stop switch is in stop position or the radar switch is in radar position, and when stop light is flashing. The Z9 flyback one shot pulse period is controlled via 0 or +5V control voltage. This controlled voltage is generated on the Misc. Logic Card (J1) where a threshold detector compares the sawtooth amplitude control voltage with a fixed reference (+5 V DC). The control voltages turns a FET switch ON or OFF to adjust the proper two or four second time constant for Z9. The output of the K_2t flyback pulse is used to stop the count from entering the K_1t range selector circuits and to trigger another one shot multivibrator Z9 on the K_2t counter card. This output pulse is called a "shift" pulse for the K_1t generator shift register. The other one shot multivibrator Z8, is a part of the K_1t generator circuit.

The K_1t generator logic and counter circuits are basically the same as the K_2t logic and counter circuits except that the K_1t generator contains a shift register to generate the step-scan sawtooth, the other difference is that when either the stop switch, linear or radar switch were pushed; each one would stop the K_1t sawtooth sweep. The K_1t flyback one-shot multivibrator as well as the other three switch transitions would trigger a one shot Z10 on the K_1t Logic card whose output triggers Z8 of K_2t counter (a one shot) which would be used as a "delayed" shift pulse. The K_1t 12 bit counter is connected to a 12 bit storage register Z8, Z9 and Z10 on the K_1t counter card. The count in the 12 bit counter is transferred to the 12 bit shift register by the shift pulse during K_2t flyback or via the "delayed" shift pulse which is generated by control panel

switches, stop, linear or radar. The K_1t generater counter is inactive during the K_2t flyback. The output sawtooth voltages are applied to the sin θ and cos θ pots.

The single-multi-scan logic circuits are found on the switch card (J3). Z3 is a Quad two input NAND gate whose input is at +5V or ground via the single-multi-scan switch. In the multi-mode, it grounds Z7 pin 10 which de-energizes the stop relay circuit and keeps the logic circuits inoperative. In the single scan mode, it opens the three (z3) NAND gates to allow either the Linear, Raster or Radar Scan switch transition to start the proper selected scan. These three switches also select the proper NAND gate of (Z2) to open gate and keep it ready for proper reset (flyback) pulse. The output of Z3 NAND triggers the one shot multivibrator Z8 (via Z5 and Z6). The Z8 output is fed to a flip flop Z4 via Z7 and Z6, to the set input. The flip flop is reset via the proper flyback pulse passing through one of the three NAND gates Z2 and then Z5 and Z7 pin 6. The Z6 flip flop output is fed via Z7 and Z6 pin 8 and J3-W to energize a transistor-relay combination on the control panel. When the relay is energized, it turns on a one-second miltivibrator which flashes the stop light on and off. At the same time, the relay opens the latching circuit for linear, raster or radar switch to kick it out of the scan selected. The stop light will flash on and off until the stop button is pressed. The proper scan switch must now be pressed to return to the single scan function. Remember, when stop light flashes, first press the stop button and then the proper scan button.

The two input NAND gates of Z9 and inverter of Z6 are used to generate necessary logic for Univ. of Pittsburgh equipment,a +5V DC while scanning and zero volts when scan is in "off" position. Z10 a Quad two input NAND gate is used to obtain proper logic for events 1, 2, 7 and 8 of the data handling system.

The MISC LOGIC card (J1) contains an inverting amplifier and threshold detector (μA749) for each K_1t and K_2t flyback one shot multivibrator control signal, 0 or +5V DC It also contains a 0.25 sec one shot multivibrator to stretch the width of the NIKKON logic pulse. This is to allow enough time to record signal in data handling system.

The Master Oscillator Card contains the Master Oscillator (13.7 KHZ) and the Buffer Amplifier (LM 310) to minimize loading effects on the K_1t and K_2t sin a and cos a pots, and in the K_1t and K_2t sweep amplitude pots.

8.0 MAIN PEDESTAL

A surplus military search light mount serves as the main pedestal for the Secede II System. This particular mount arrived in excellent condition; and appeared to have never been used and was stored inside for many years. As such, the mechanical components (such as bearings and gears) needed no rework with the exception of the elevation drive gear. The electrical wiring and connections needed replacement since long storage had deteriorated the insulation. Wiring schematics are shown in Figures 8-1 through 8-16.

A triangular base was fabricated to support the entire amount and replace the trailer which was inappropriate for an optical mount. The search light optics were discarded and a bridge structure was fabricated. Detailed drawings of each of the components are provided separately from this report.

The control system for the main pedestal consists of synchro generator (CX) on the azimuth and elevation axis and control transformers (CT) in the manual sighting station and scan computer. The control system generates an error signal when the shaft positions between a generator/transformer are dissimilar. The error signal is amplified to drive the main pedestal in the proper direction to cause a nulling of the error signal. A detailed evaluation of this servo system is provided later in this report.

The readout of elevation/azimuth angle is performed by two synchro-to-digital converters contained in the video console. These readouts are driven directly from the mount generators. After the optical system has been aligned (see alignment - Optical Systems), the servo system is aligned to give absolute position information. An accurately surveyed stake is observed through the interferometer and the mount locked with the survey point centered in the focal plane aperture. The synchro generators are rotated to yield the

proper value of azimuth and elevation angle. The manual sighting station is rotated so that the optical sight is centered on the same boresight point. The two manual sighting station potentiometers are rotated on their shafts to yield the proper output for the survey angle; 0 volts being the zenith angle and +100 volts the horizontal; +10 volts being true north in azimuth. For example, if the survey point were 90^{0} zenith and 270^{0} azimuth the output of the respective potentiometers are 0 volts elevation and 7.5 volts azimuth. Next the CT's in the manual station are nulled by monitoring the error signal and rotating the control transformers until zero signal is observed. Care must be taken to be sure the proper null is obtained since there are two; a true and false for each CT. A true null causes the servo system to drive the mount toward null when the CT and the CX shafts are misaligned. The scan computer CT's are aligned in a similar fashion.

8.1 Schematics - Main Pedestal

Figures 8-1 through 8-11 show in detail the various electrical details of the main mount wiring harness.

8.2 Mount Servo Analysis

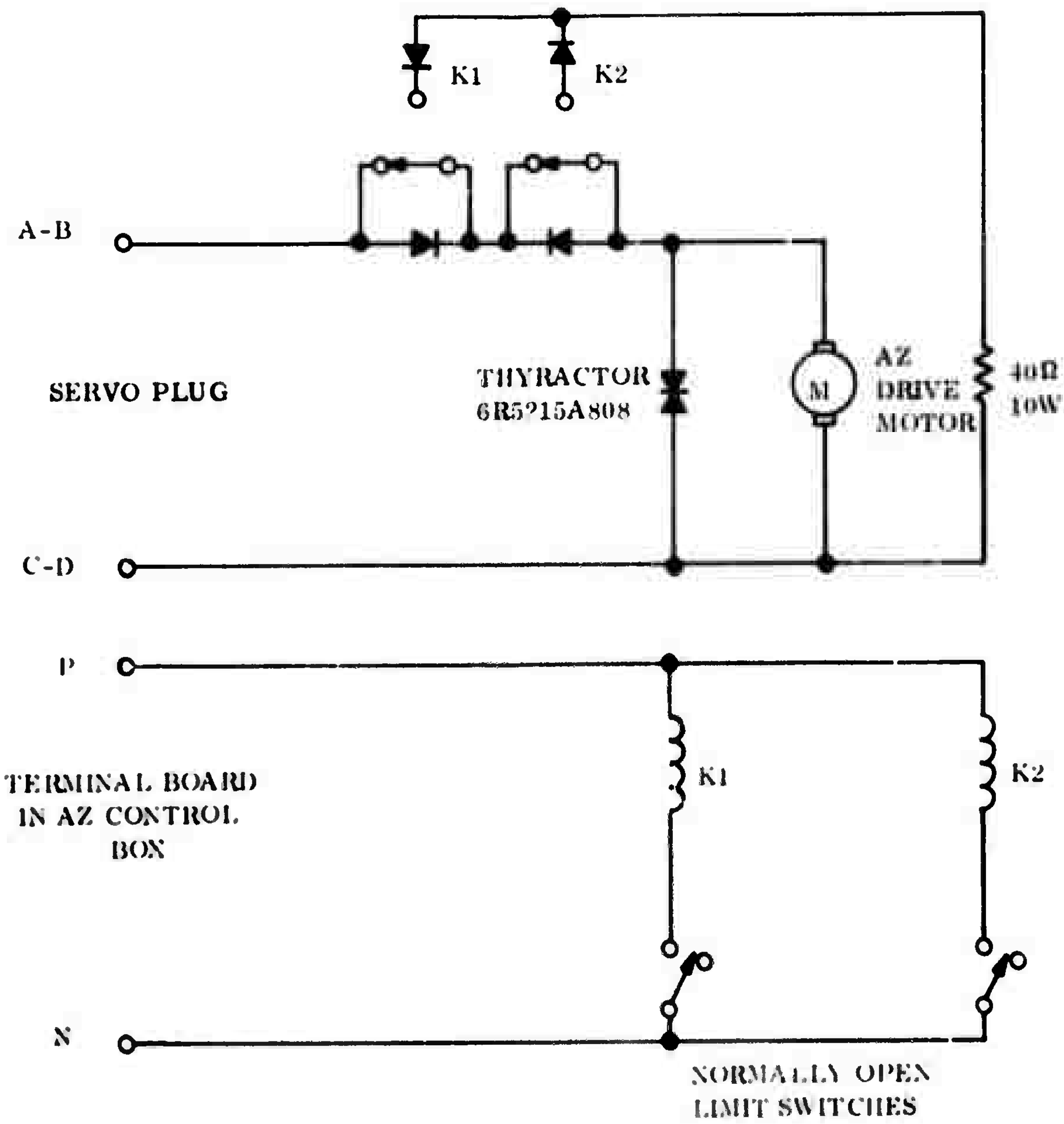
The approach taken in defining the azimuth and elevation drive characteristics and the resulting implementation are documented in this section. Specific design goals in performance are listed below and are ordered in degree of importance.

1. Minimize overshoot to step inputs. Both drive axes must be limited to one overshoot; the amount of this overshoot is much more critical in elevation than in azimuth.

2. Follow a constant rate (10 degrees per second maximum) with less than 0.5 degree of error.

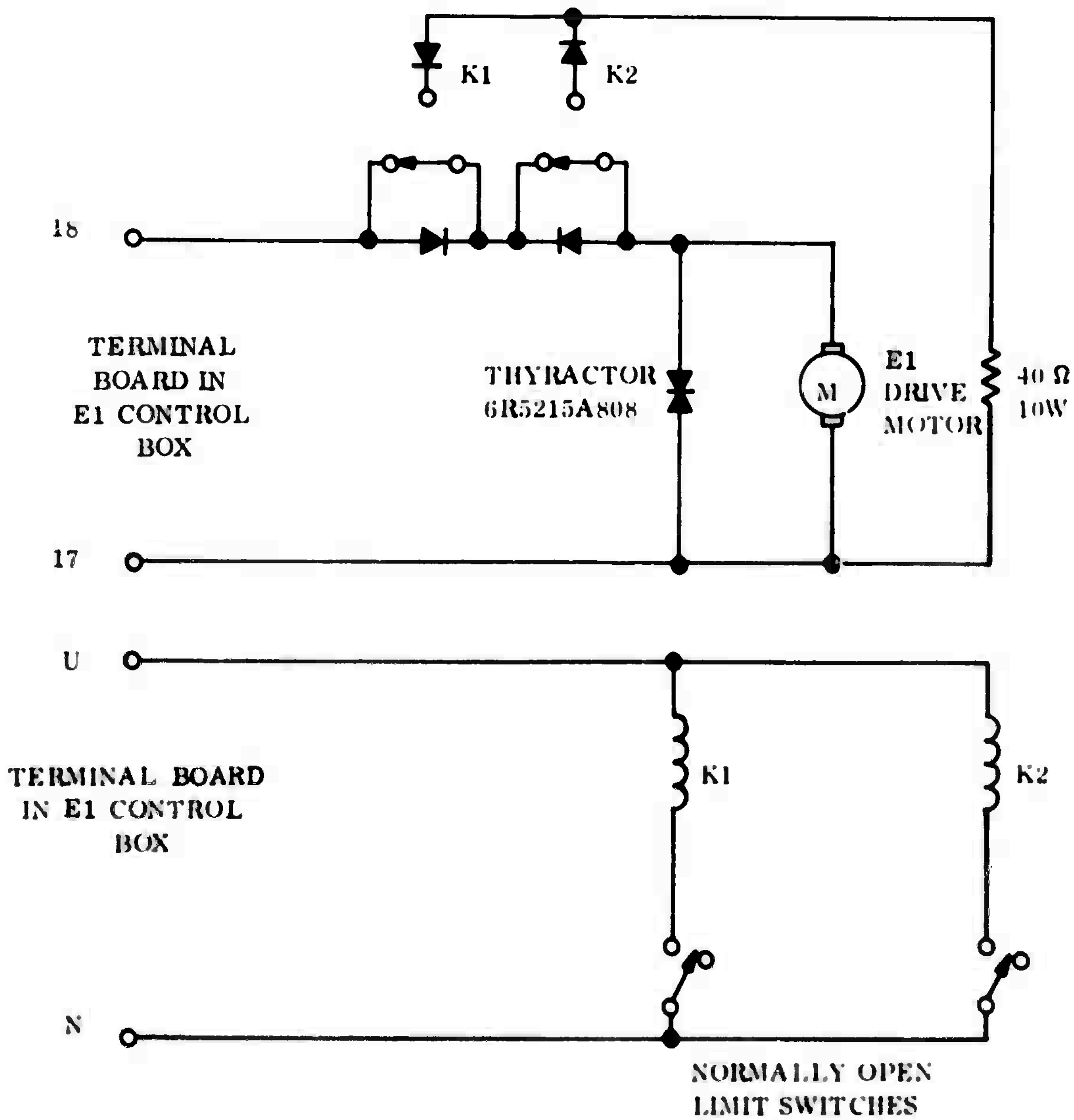
3. Present a smooth response to operator inputs.

4. Hold steady (to within 0.5 milliradian) for a constant position command.



ALL DIODES IN1128
K1 AND K2 SHOWN IN DE-ENERGIZED POSITION WHEN A (+) VOLTAGE AT A-B DRIVES THE AXIS INTO A LIMIT SWITCH, THE RELAY K2 MUST BE ENERGIZED BY THAT LIMIT SWITCH.

Figure 8-1. Azimuth Drive Schematic



ALL DIODES 1N1128
K1 AND K2 SHOWN IN DE-ENERGIZED POSITION WHEN A (+) VOLTAGE AT 18 DRIVES THE AXIS INTO A LIMIT SWITCH, THE RELAY K2 MUST BE ENERGIZED BY THAT LIMIT SWITCH.

Figure 8-2. Elevation Drive Schematic

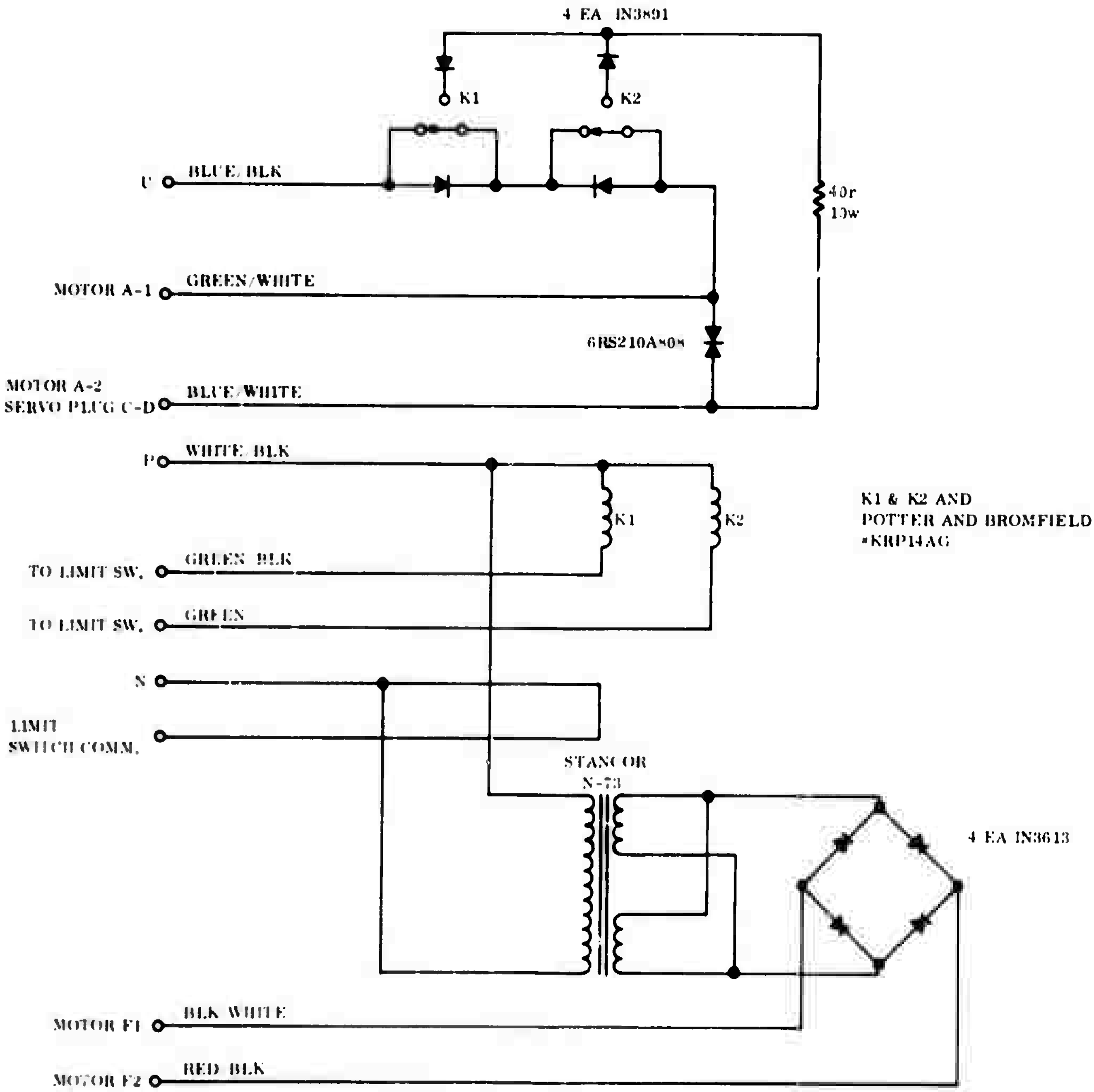


Figure 8-3. Azimuth Limit and Blockout Chassis Schematic

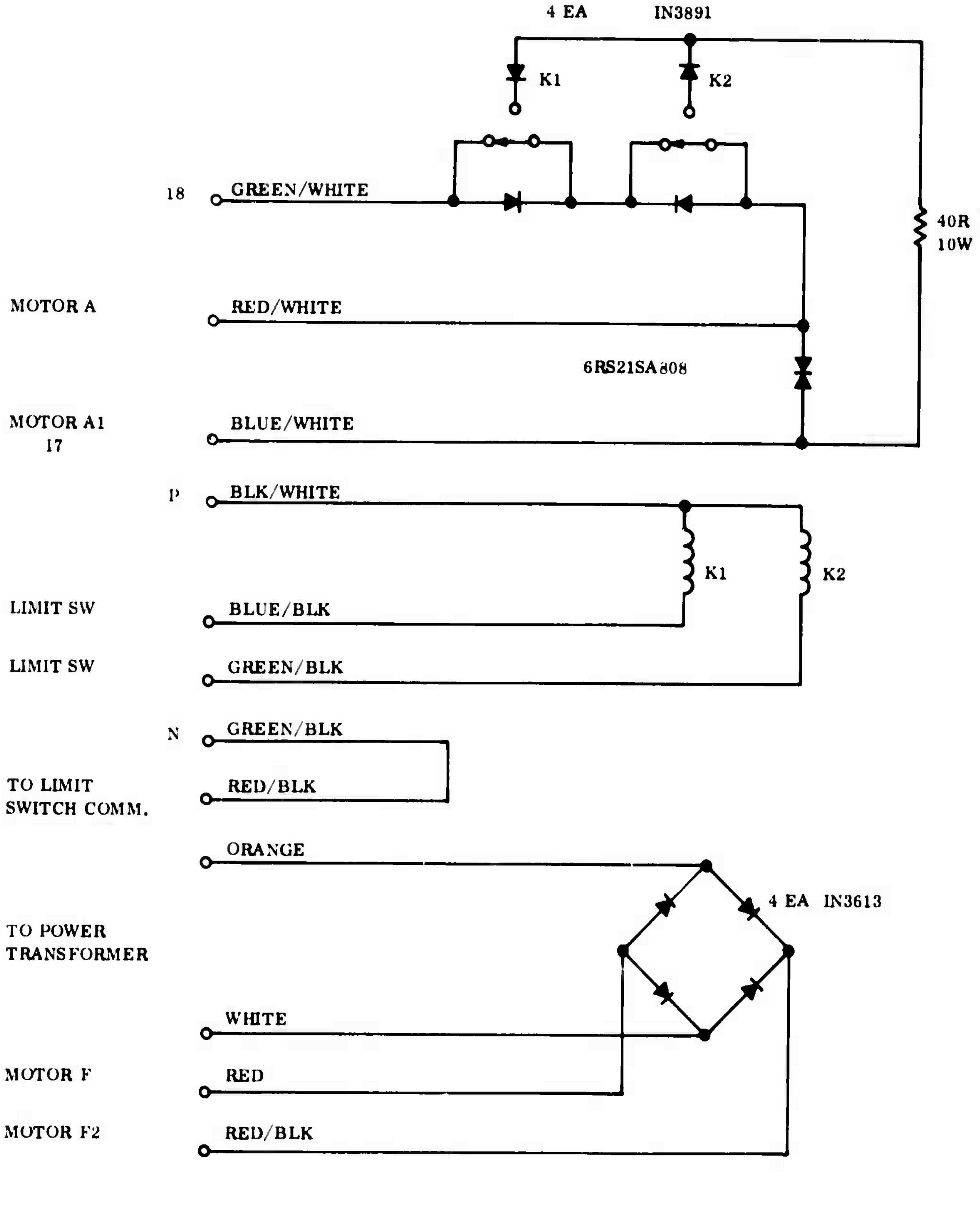


Figure 8-4. Elevation Limit and Blockout Chassis Schematic

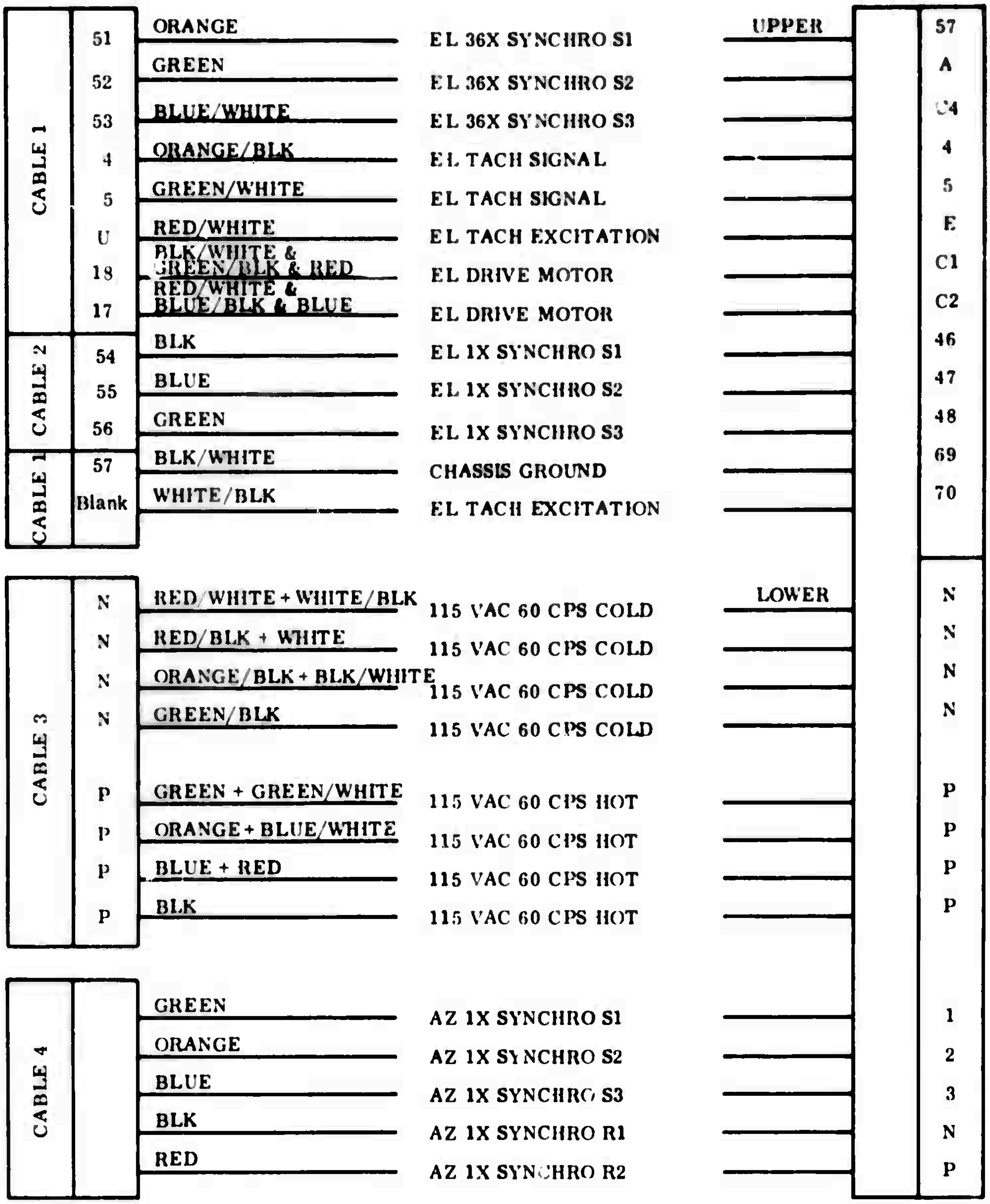


Figure 8-5. Ship Rings to Azimuth Control Box Wiring Diagram

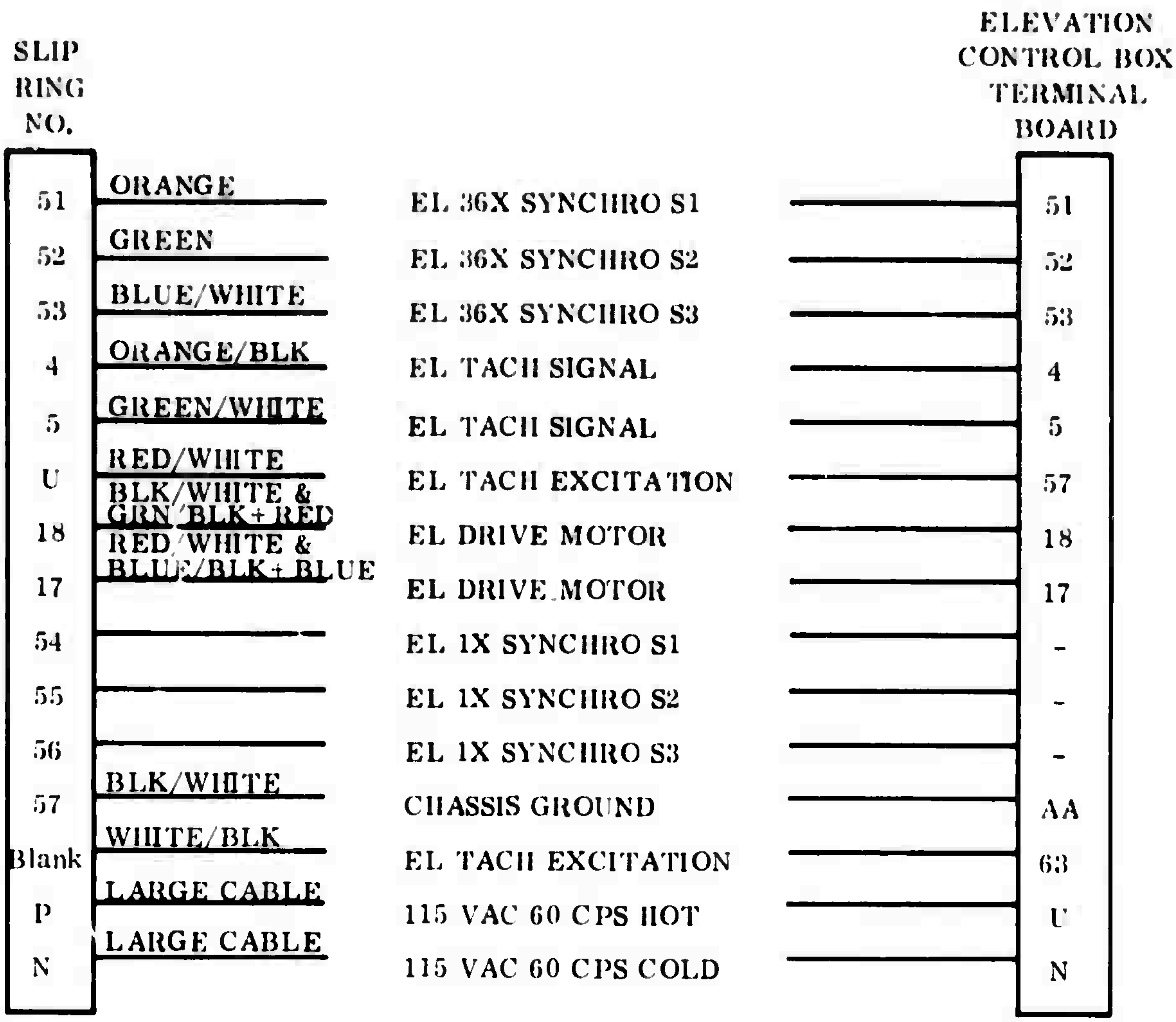


Figure 8-6. Ship Rings to Elevation Control Box Wiring Diagram

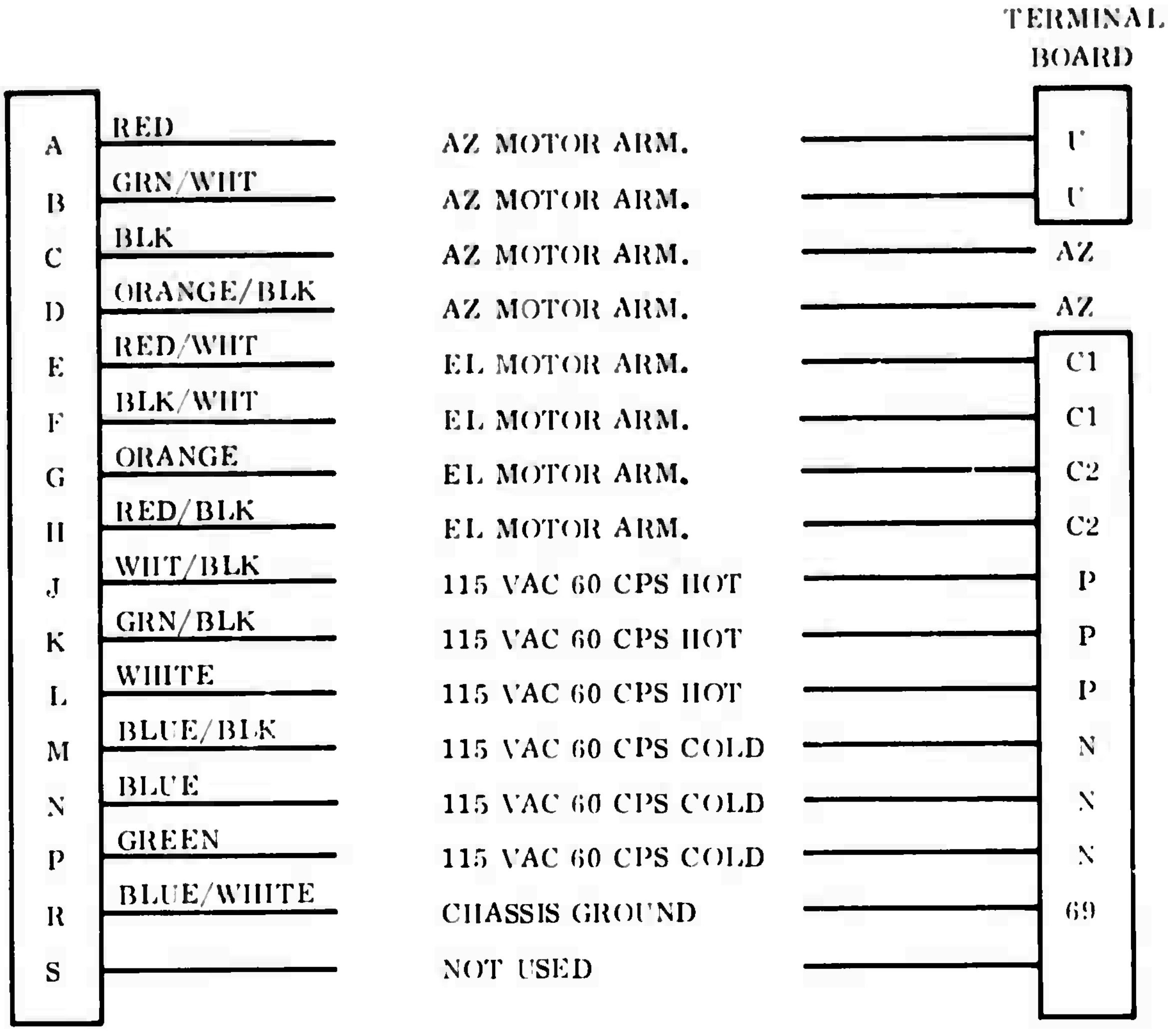


Figure 8-7. Servo Plug to Azimuth Control Box Wiring Diagram

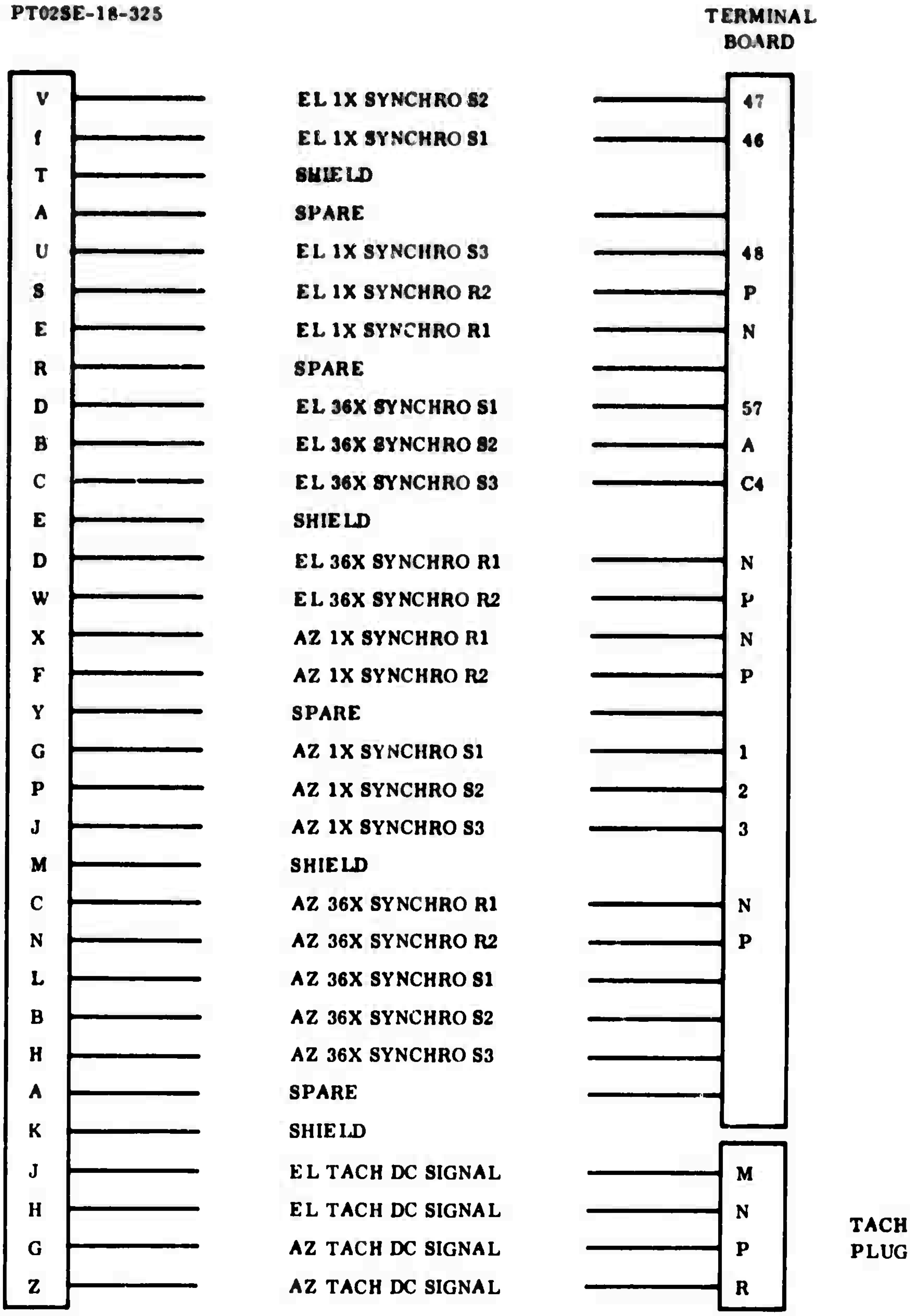


Figure 8-8. Synchro Plug to Azimuth Control Box Wiring Diagram

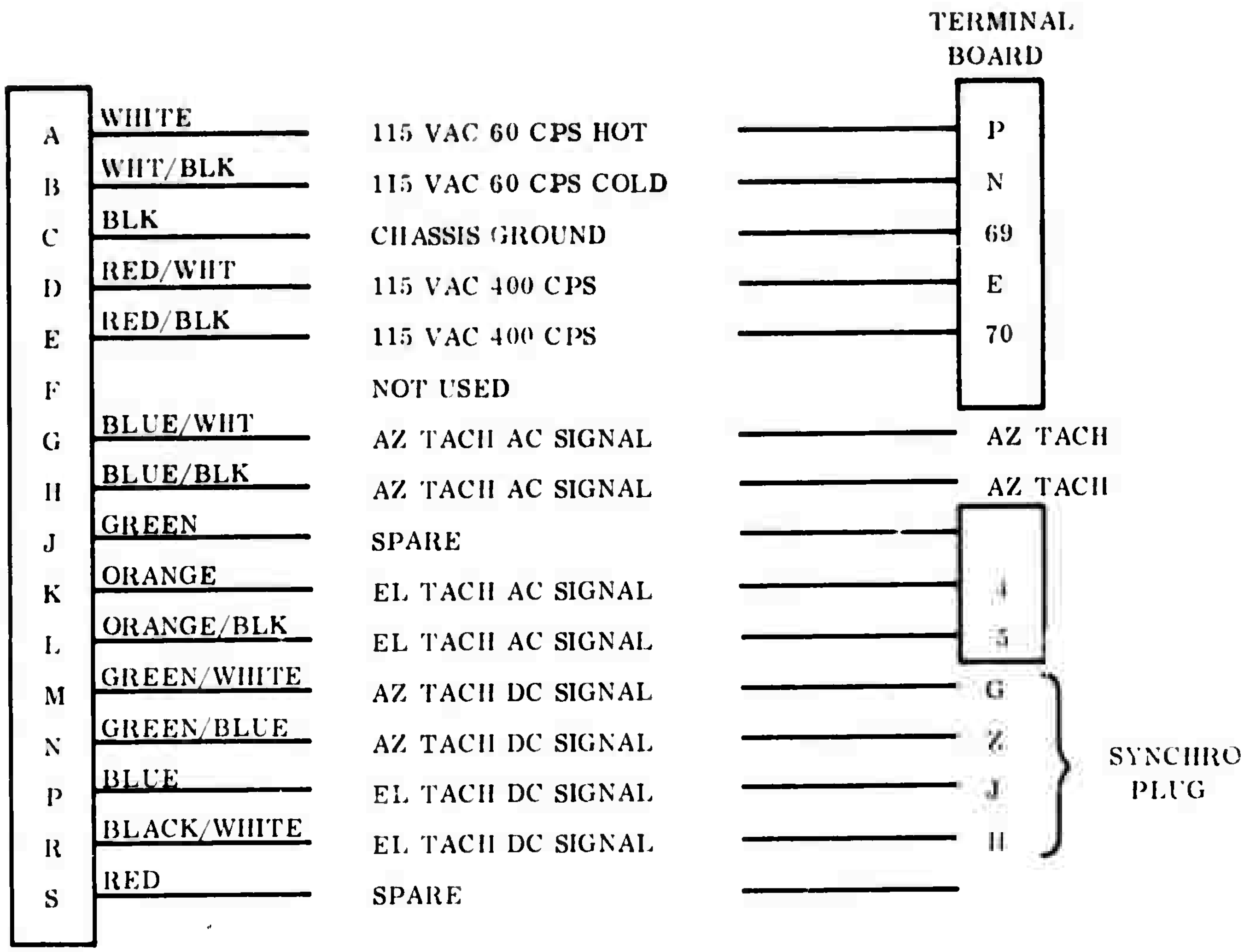


Figure 8-9. Tachometer Plug to Azimuth Control Box Wiring Diagram

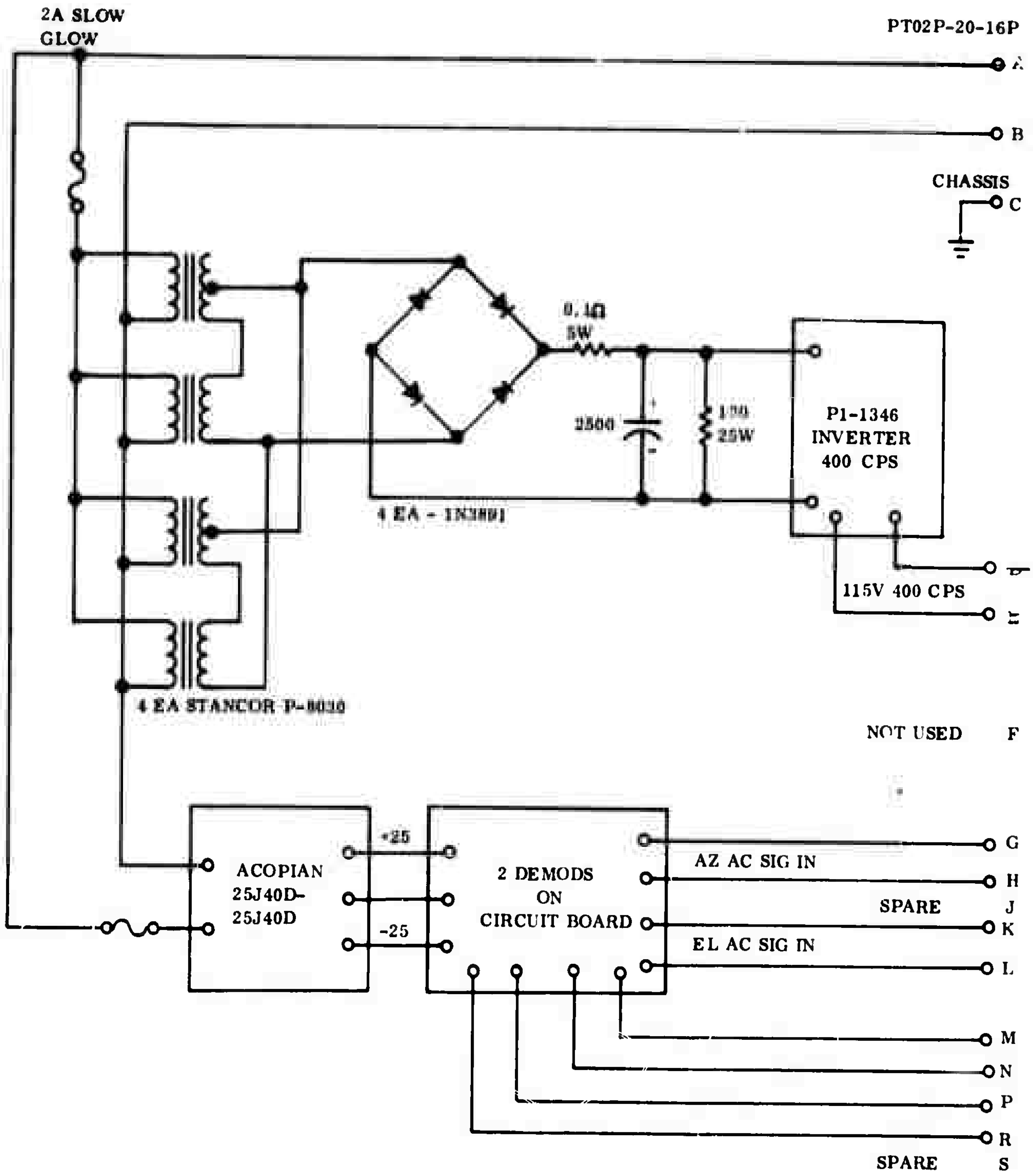


Figure 8-10. Tachometer Control Chassis Schematic

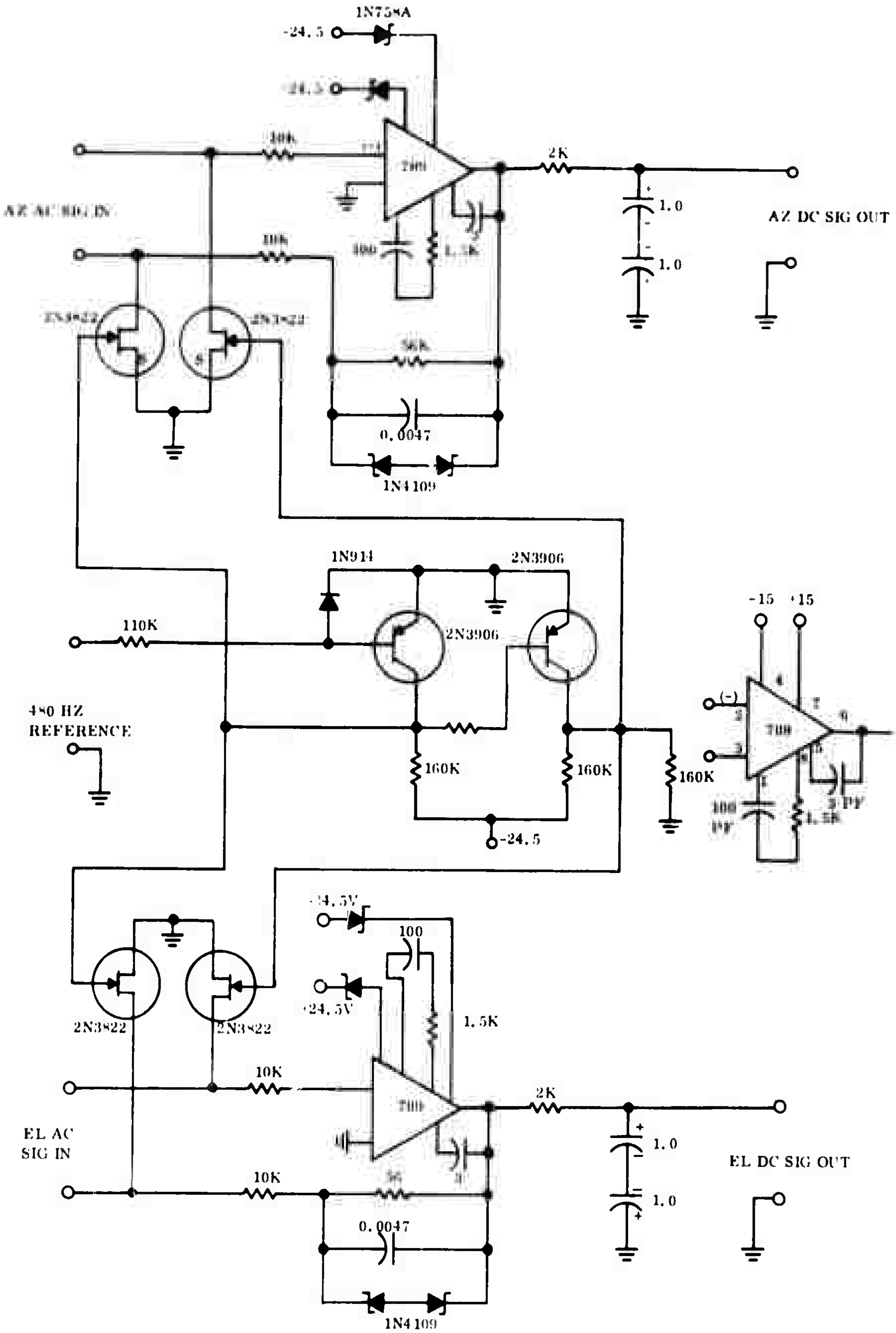


Figure 8-11. Tachometer Demodulator Schematic

A brief description of the control loop (including sensors, actuators and electronics) used for driving each axis of the telescope is shown in Figure 8-12.

The telescope is driven by position command, either through a manual position controller or an analog computer. Azimuth and elevation position commands are compared to 1 and 36 speed synchro transmitter signals on each axis in differential synchros to develop position error signals. These error signals are demodulated, producing a DC voltage used in conjunction with rate information to reduce the sensed position error.

Rate is sensed by AC tachometer for the purpose of introducing minor loop compensation (if necessary) and for maintaining more accurate control of the load response to step commands. The tachometer output signals are demodulated, presenting a DC voltage proportional to load rate which is capacitively coupled to the summing amplifier for comparison with position error signals. Blocking steady state rate signals from the summing amplifier avoids introduction of excessive position offsets to constant rate commands, allowing the loop design to approach the position offset requirements.

Servo error (rate + position error) is then amplified in a power amplifier and sent to a DC torque motor on the telescope mount. Torque amplification is obtained from gear trains on both azimuth and elevation axes.

8.3 Determination of Component Transfer Functions

Figure 8-13 orders azimuth or elevation axes into component blocks suitable for determining specific transfer functions. Table 8-1 lists these transfer characteristics with their present gain and frequency functions. Gain in the summing amplifier, the rate feedback loop and the position synchro demodulator have been set to optimize azimuth and elevation drive performance. The remainder of this section describes (where necessary) how each component transfer function in Table 8-1 was obtained.

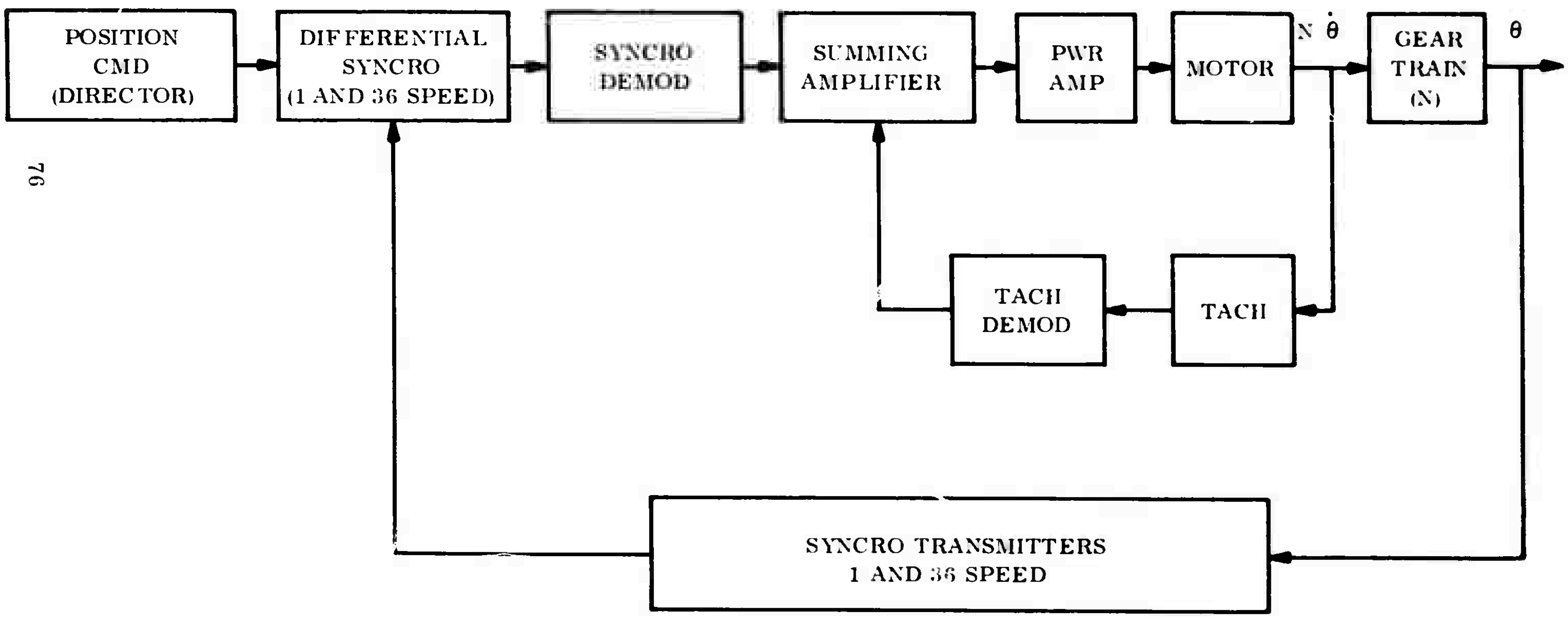


Figure 8-12. Hardware Definition

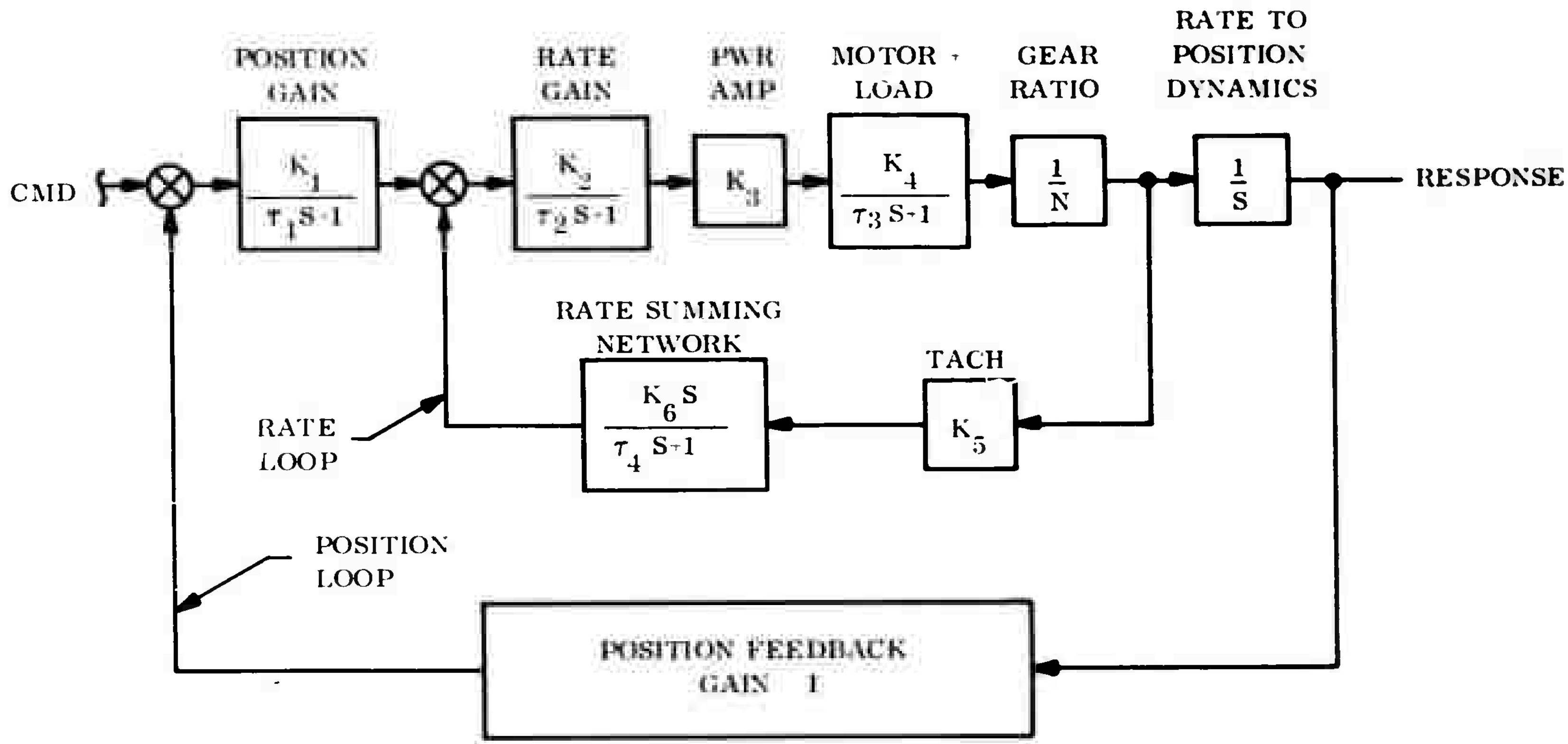


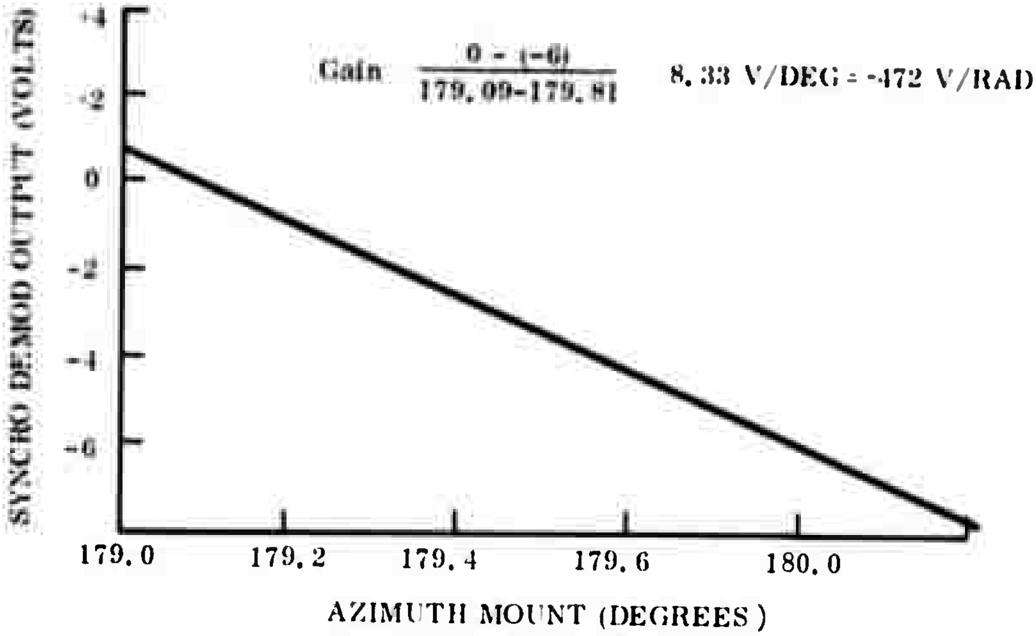
Figure 8-13. Linear Rate and Position Representation

Table 8-1. Component Transfer Functions

Parameter	Form	Present Value: Azimuth	Present Value: Elevation
Position Gain	$\frac{K_1}{\tau_1 S + 1}$	$\frac{472}{0.01\ S + 1}\ \frac{\text{volts}}{\text{radian}}$	$\frac{325}{0.007\ S + 1}\ \frac{\text{volts}}{\text{radian}}$
Rate Gain	$\frac{K_2}{\tau_2 S + 1}$	$\frac{3.125}{0.005\ S + 1}\ \frac{\text{volts}}{\text{volt}}$	$\frac{3.125}{0.005\ S + 1}\ \frac{\text{volts}}{\text{volt}}$
Power Amplifier	K_3	10 v/v variable	10 v/v variable
Motor + Load	$\frac{K_4}{\tau_3 S + 1}$	$\frac{0.893}{0.07\ X + 1}\ \frac{\text{rad/see}}{\text{volt}}$	$\frac{0.893}{0.02\ S + 1}\ \frac{\text{rad/sec}}{\text{volt}}$
Gear Ratio	N	360	645
Tachometer	K_5	36.8 V/rad/see	18.1 V/rad/sec
Rate Summing Network	$\frac{K_6 S}{\tau_4 S + 1}$	$\frac{0.128\ S}{0.16\ S + 1}\ \frac{\text{volts}}{\text{volt}}$	$\frac{0.032\ S}{0.2\ S + 1}\ \frac{\text{volts}}{\text{volt}}$

8.3.1 Position Gain. The DC gain of the 36 speed synchro and eleetronics was determined experimentally by reading demodulator output voltage for varying mount positions. Figure 8-14 shows this data for azimuth and elevation axes. The lag in the transfer function is a 60 Hz filter on the demodulator buffer amplifier.

8.3.2 Rate Gain. Two inputs are eompared in the summing amplifier (see Figure 8-12). The gain of this amplifier is defined as that presented to the position error signal.



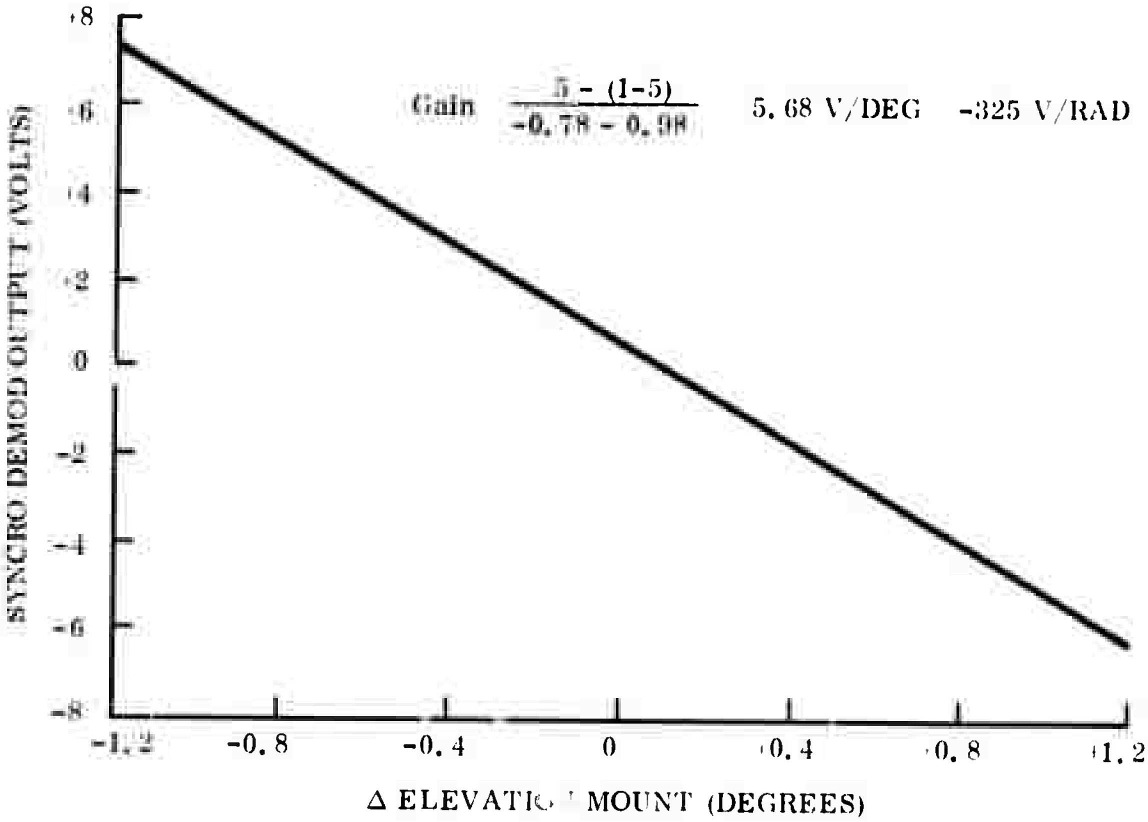


Figure 8-14. Azimuth and Elevation Position Gain Calculation

The gain presented to the rate signal (see Figure 8-13) is split between K_2 and K_6, such that the product is equal to the total gain to a rate signal.

8.3.3 Power Amplifier. A gain of 10 volts/volt is available from the power amplifiers. This gain should nominally be set to maximum to avoid saturation of the other amplifiers, and to realize the maximum (75 volts) power amplifier output.

8.3.4 Motor + Load. Voltage control of a motor and load drive can be modeled as in Figure 8-15. Data taken on the drive motors allow calculation of the motor constants as follows:

a. K_T/R -- Torque Constant of the Motor:

	Data				Calculation	
	Torque	Volts		Gear Ratio	$K_T/R = \frac{\text{Torque}}{\text{Volts}}$	$R = \frac{\text{Volts}}{\text{Amps}}$
Azimuth	330 ft-lb	35 V	1.5A	360	0.0262 $\frac{\text{ft-lb}}{\text{volt}}$	23.33 ohm
Elevation	213.5 ft-lb	14V	0.62A	644.8	0.02365 $\frac{\text{ft-lb}}{\text{volt}}$	22.58 ohm

b. K_B - Voltage Constant (Back EMF) of the Motor - This was done for the azimuth motor and assumed to be the same for elevation, since the characteristics calculated in "a" above show the motors to be similar. The turret completes a full revolution in 40 seconds with 75 volts applied to the motor. Current necessary to sustain this rate was measured at 0.5 ampere. Therefore, back EMF can be calculated as follows:

$$\text{BEMF} = 75 - 0.5(R) = 63.33 \text{ volts}$$

Motor speed equals the turret speed times the azimuth gear ratio (360) or:

$$\frac{2\pi \text{ rad}}{40 \text{ sec}} \times 360 = 18\,\pi \text{ rad/sec}$$

Therefore:

$$K_B = \frac{\text{BEMF}}{\text{Motor Speed}} = \frac{63.33}{18\pi} = 1.12 \text{ v/rad/sec}$$

c. Motor + Load Gain and Time Constant - The motor + load model in Figure 8-15 has a closed loop transfer function as follows:

$$\frac{\text{Rate Out}}{\text{Volts In}} = \frac{K_T/RJS}{1 + \frac{K_T K_B}{RJS}} = \frac{1/K_B}{1 + \frac{RJS}{K_T K_B}}$$

This expression fits the form defined in Table 8-1 with:

$$K_4 = 1/K_B = 0.893 \text{ Rad/sec/volt}$$

$$\tau_3 = \text{motor + load time constant} = \frac{RJ}{K_T K_B}$$

An exact expression of motor + load inertia was not determined (and is not expected to be determined). Therefore, the evaluation of the time constant was performed through detailed inspection of scope pictures taken of the step response in azimuth and elevation axes (shown in Figure 8-16). Figure 8-17 shows reconstructed sketches of these step responses for azimuth (with elevation at zero and zenith) and for elevation axis drives. The theoretical time response to a step for the motor + load transfer function developed here is:

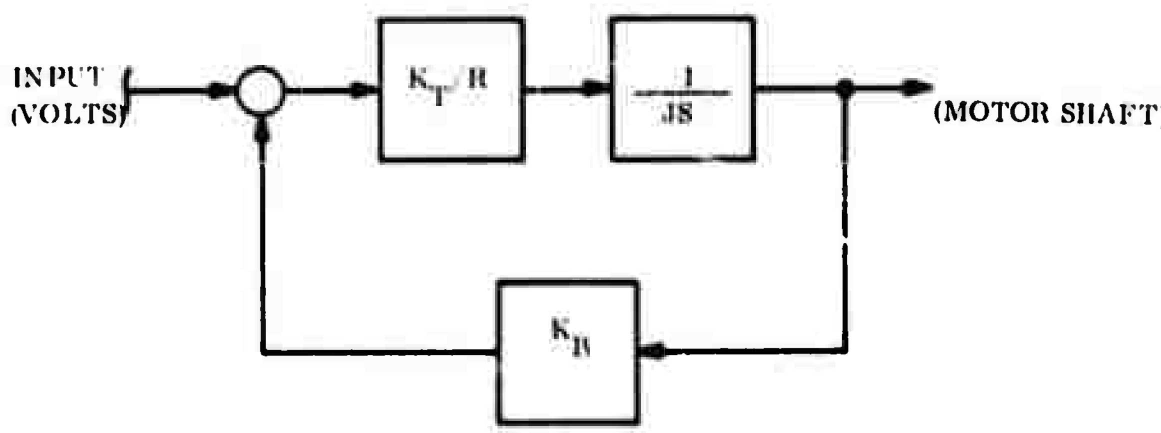
$$\text{Rate Output} = \text{Final Rate } [1 - e^{-t/\tau_3}]$$

From Figure 8-17 we can locate that time at which the response has reached $(1 - e^{-1}) = 63\%$ of its final rate. That time interval is then equal to the motor + load time constant, τ_3. For azimuth, this value is 70 milliseconds and for elevation it is 20 milliseconds.

It is recognized that location of the motor + load break by this method is not extremely accurate. However, since both azimuth and elevation breaks are above their respective servo bandwidths, a 15 to 20% accuracy is all that is necessary.

d. Load Inertia - Though not necessary for completion of the servo analysis, an estimate of load inertia can be obtained through use of the above time constants and its mathematical expressions, i.e.:

$$\tau_3 = \frac{RJ}{K_T K_B}$$

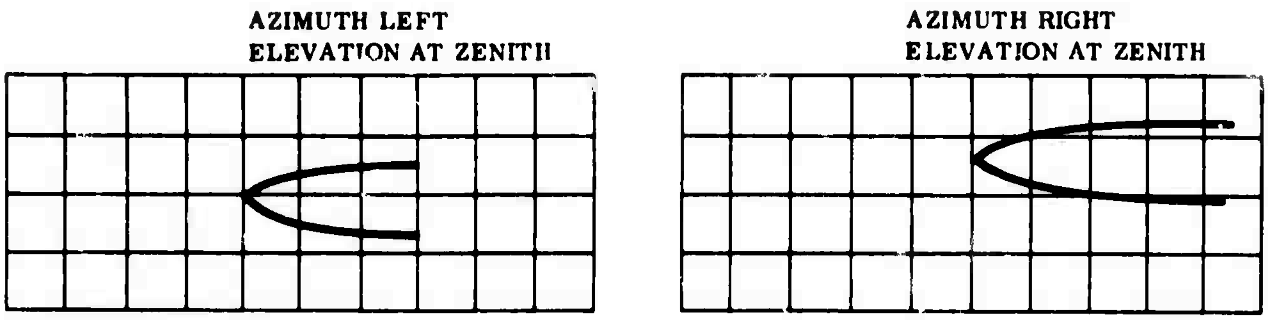


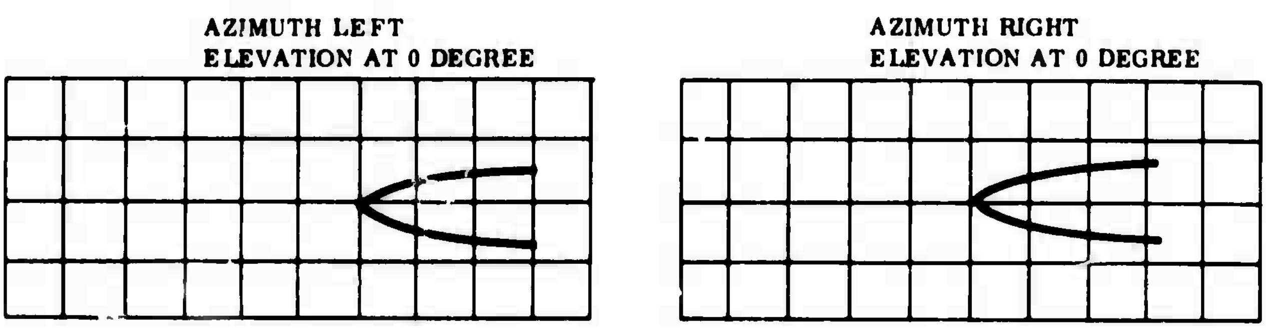
WHERE K_T/R TORQUE CONSTANT OF THE MOTOR

J MOTOR + LOAD INERTIA REFERRED TO THE MOTOR

K_B VOLTAGE CONSTANT (BACK EMF) OF THE MOTOR

Figure 8-15. Motor Plus Load Model





NOTES:

1 SCOPE TRACES AT TACH DEMOD INPUT
2 75V AT MOTOR TERMINALS
3 SCALE: VERTICAL DIVISION = 2V/CM
HORIZONTAL DIVISION = 100 MS/CM

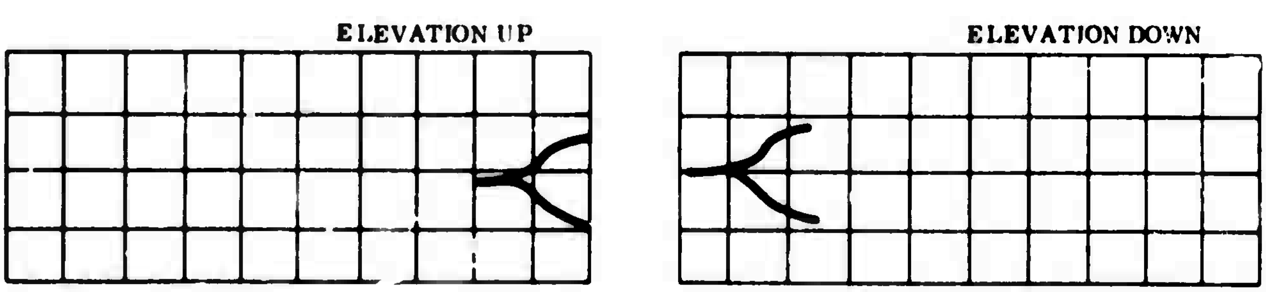


Figure 8-16. Motor Plus Load Characteristics

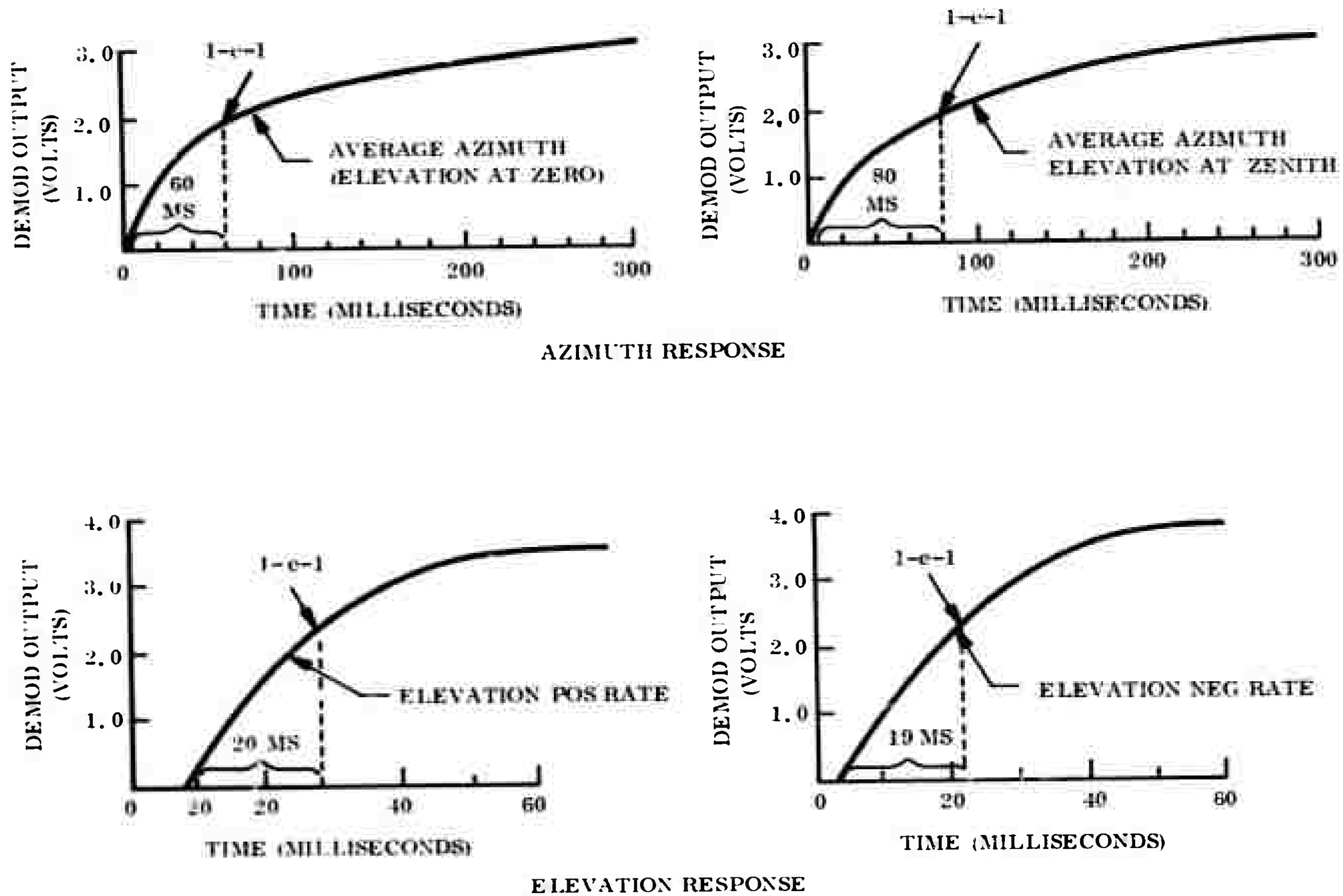


Figure 8-17. Average Motor Plus Load Characteristics

$$J \text{ (referred to the motor)} = \frac{\tau_3 K_T K_B}{R}$$

$$J \text{ (referred to the load)} = J \text{ (motor)} \times N^2$$

Therefore:

$$J \text{ elevation} = (644.8)^2 \; (0.02365) \; (1.12) \; (20) \; (10^{-3}) = 220 \text{ slug-ft}^2$$

$$J \text{ azimuth} = (360)^2 \; (0.0262) \; (1.12) \; (70) \; (10^{03}) = 267 \text{ slug-ft}^2$$

8.3.5 Tachometer Gain. The tachometers are physically mounted at each motor with a 1:1 belt drive. However, for purposes of analysis, the tach loop is defined at the turret rates instead of motor rates. It is then necessary to modify measured tach gain, in volts out per motor RPM, by the respective axis gear ratio. Both tachs are identical, but because the demodulators are dependent upon minor variations in component values, their overall gains are different.

Elevation: Demod out = 1.5 volts for 75 volts on the motor

Azimuth: Demod out = 5.8 volts for 75 volts on the motor

Since 75 volts on the azimuth motor has been previously shown to produce a turret rate of $\pi/20$ rad/sec, the azimuth tach gain can be calculated as:

$$\text{Azimuth Tach Gain} = 5.8 \left(\frac{20}{\pi}\right) = 36.8 \text{ volts/rad/sec}$$

Elevation tach gain is based on the same motor speed, but modified by the difference in gear ratio and demodulator output voltage, i.e.:

$$\text{Elevation Tach Gain} = 5.1 \text{ volts} \left(\frac{20}{\pi}\right)\left(\frac{360}{645}\right) = 18.1 \text{ volts/rad/sec}$$

8.3.6 Rate Summary Network. The steady state rate is not fed back through the tach loop in order to avoid excessive position offsets to a constant rate command. This is accomplished through the use of a blocking capacitor as shown in Figure 8-18.

The rate summing network transfer function can be obtained by developing an expression for e_o/e_i in Figure 8-18, except that the result will automatically include the rate gain previously assigned as K_2. Therefore, we can write the following:

(Rate Summing Transfer) X (K_2 = e_o/e_i

Where

$$K_2 = R_2/R_3$$

Therefore:

$$\text{Rate Summing Transfer} = (e_o/e_i)\left(\frac{R_3}{R_2}\right)$$

From Figure 8-18 we can write:

$$e_o/e_i = \frac{R_2}{R_1 + \frac{1}{SC}} = \frac{R_2\,SC}{SC\,R_1 + 1}$$

Therefore:

$$\text{Rate Summing Transfer} = \frac{R_2\,SC}{SC\,R_1 + 1}\left(\frac{R_3}{R_2}\right) = \frac{SC\,R_3}{SC\,R_1 + 1}$$

This fits the form shown in Table 8-1 with $K_6 = C\,R_3$ and $\tau_4 = C\,R_1$. Position and rate loop gains can be set by proper selection of the resistors and capacitor values R_1, R_2, R_3 and C. This was done, arriving at azimuth and elevation loop responses considered to be optimum for the requirements listed in the introduction. Component values finally chosen were as follows:

	R_1	R_2	R_3	C	$K_6 = CR_2$	$\tau_4 = CR_1$
Azimuth	200K	500K	160K	0.8μ fd	0.128 v/v	0.16 sec
Elevation	1 meg	500K	160K	0.2μ fd	0.032 v/v	0.2 sec

8.4 Loop Response

The trial and error approach in selecting values for R_1, R_2, R_3 and C by observing their effect on loop response to manual commands still leaves questions to be answered. This section is an attempt to estimate, through use of the linear transfer functions defined in Section 8.3, how well the system follows step and rate commands. It also presents the frequency functions of both position loops in bode plots, indicating bandwidth, degree of stability and low frequency gain.

8.4.1 Frequency Response. For purposes of determining overall closed loop transfer functions, can be reduced as shown in Figure 8-19. Expressions for these functions can be obtained by combining transfer functions in Table 8-1 and are listed as follows:

	G_1	N_1	G_2	K_1	D_1
Azimuth	$\frac{1}{(S/200+1)(S/143+1)}$	$4.71\ S$	$\frac{472\ S}{0.01\ S+1}$	0.0775	$S/6.25+1$
Elevation	$\frac{1}{(S/200+1)(S/50+1)}$	$0.58\ S$	$\frac{325}{0.007\ S+1}$	0.0433	$S/5+1$

The table and Figure 8-19 express the minor (or rate) loop terms in a form that allows easy identification of closed loop gain and frequency terms, i.e.:

$$\text{Rate Closed Loop Transfer} = \frac{K_1 G_1}{1 + \dfrac{K_1 G_1 N_1}{D_1}} = \frac{K_1 D_1}{\dfrac{D_1}{G_1} + K_1 N_1}$$

A computer program was used to factor the denominator polynominal obtained when the expression for G_1, D_1, K_1, and N_1 were introduced, with results as follows:

$$\text{Azimuth Rate Loop Transfer} = \frac{0.0775\,(S/6.25+1)}{(S/1.73+1)(S/69+1)(S/150+1)}$$

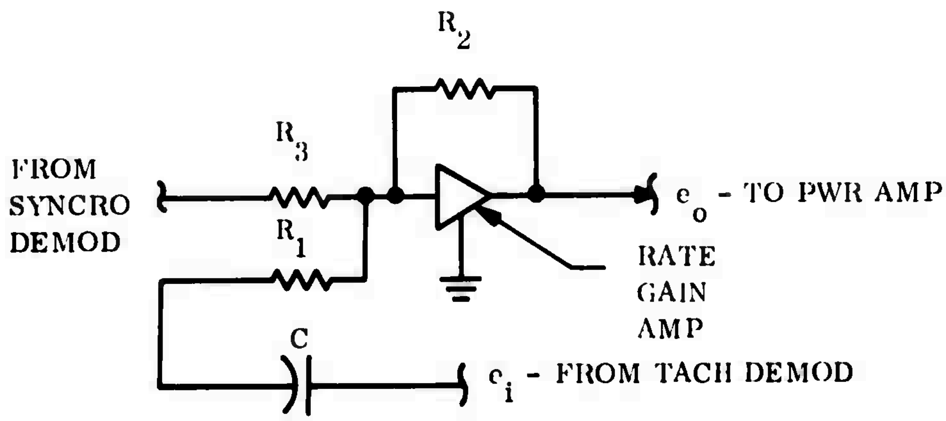


Figure 8-18. Calculation of Rate Summing Transfer Function

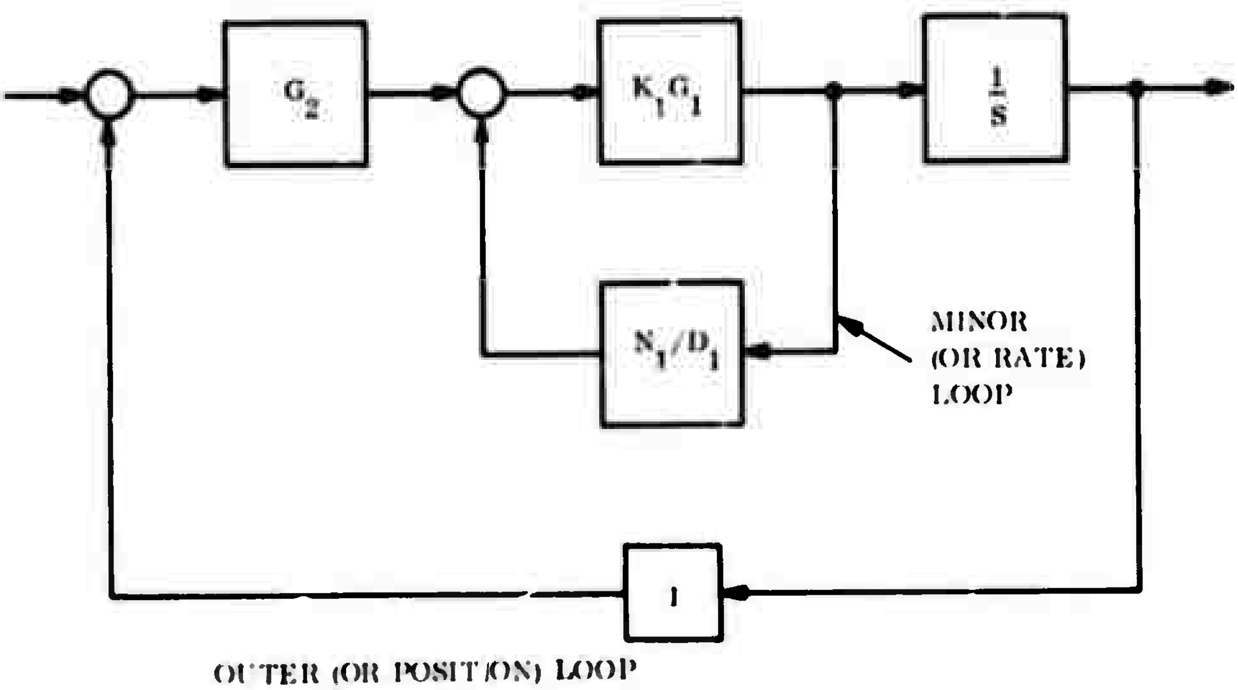


Figure 8-19. Calculation of Overall Loop Transfer Function

$$\text{Elevation Rate Loop Transfer} = \frac{0.0433\,(S/5 + 1)}{(S/4.44 + 1)\,(S/60 + 1)\,(S/191 + 1)}$$

With the above closed loop rate transfer functions, simply multiply by the outer (position) loop term to obtain expressions for the outer loop open loop transfer functions. These are plotted in Figures 8-20 for azimuth and 8-21 for elevation.

Both axes were to exhibit a minimum amount of overshoot in response to a step input. This is done by minimizing the amount of lead information presented to the outer (or position) loop by the inner (or rate) loop. It is obvious from Figures 8-20 and 8-21 that doing this forces the use of higher bandwidth or smaller low frequency gain. To avoid approaching the motor + load breaks, bandwidth was limited to 10 - 20 radians/second. Therefore DC gain was sacrificed to insure minimum overshoot responses. Also of note is that the elevation loop is purposely more heavily damped than azimuth because of the desire to minimize the chances of damage to experimental equipment on the turret, and to reduce jitter effects in the elevation gear train (the elevation gear train has twice the gain of azimuth, making the effects of backlash more pronounced.

8.4.2 Step and Ramp Response. The system closed loop response is obtained by introducing the position open loop transfer functions into the computer program discussed in Section 8.4.1. This program also has the capability of plotting unit step and ramp responses which are shown in Figures 8-22 through 8-25. From these figures it can be seen that:

a. There is one over-shoot to a step command. For elevation this is minimal (4%) and for azimuth it is 23%.

b. Both systems settle to within 1.25% of the step input value by 0.6 second.

Position offset to constant rates are derived from Figures 8-24 and 8-25. Here the effects of a lower position loop gain in elevation are apparent. a 10 degree/second command produces a steady state lag of 0.65 degree in elevation and only 0.24 degrees in

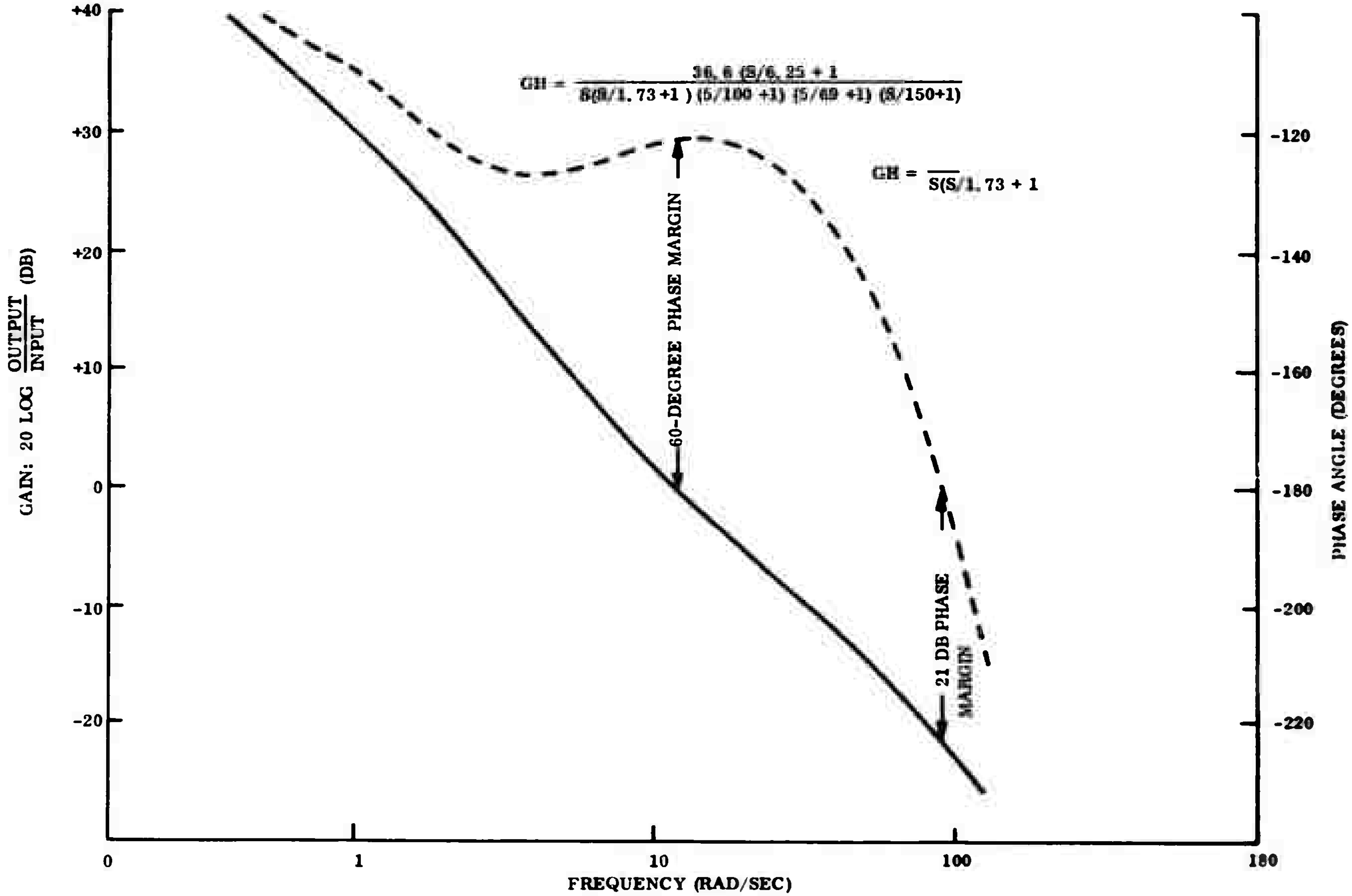


Figure 8-20. Azimuth Axis Open Loop Gain and Phase

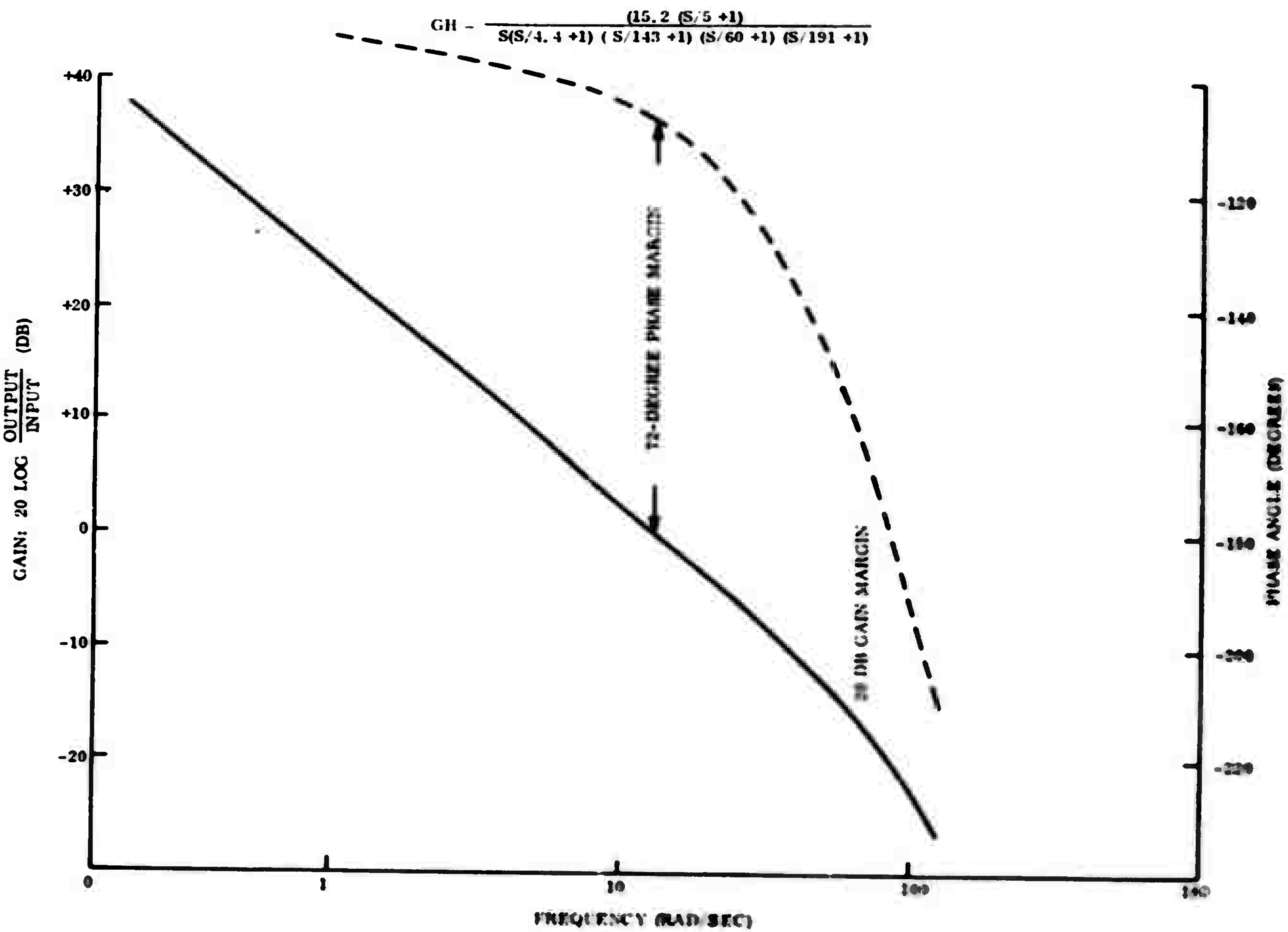


Figure 8-21. Elevation Axis Open Loop Gain and Phase

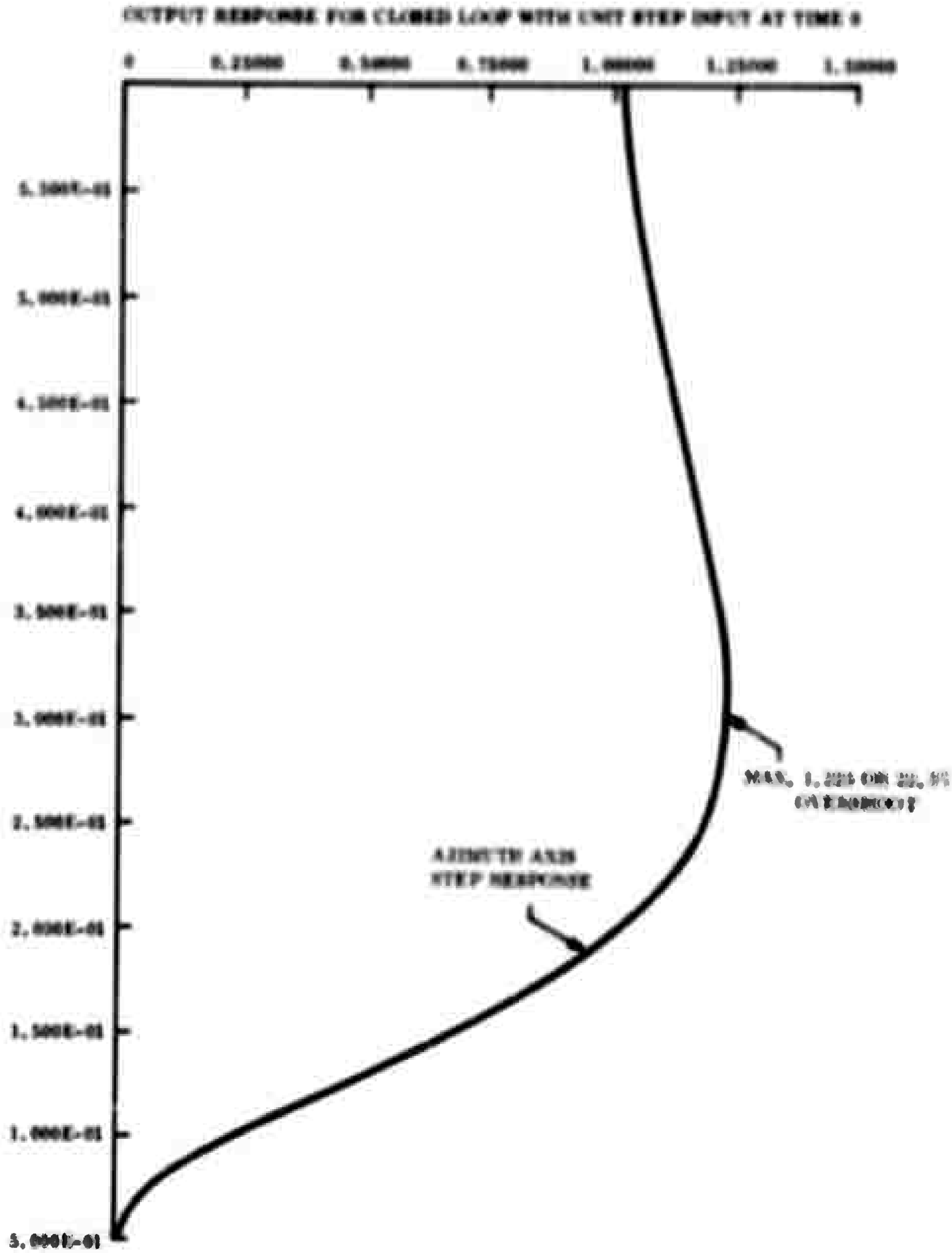


Figure 4-22. Azimuth Position Loop Step Response (Corrected for Motor Plus Load Break)

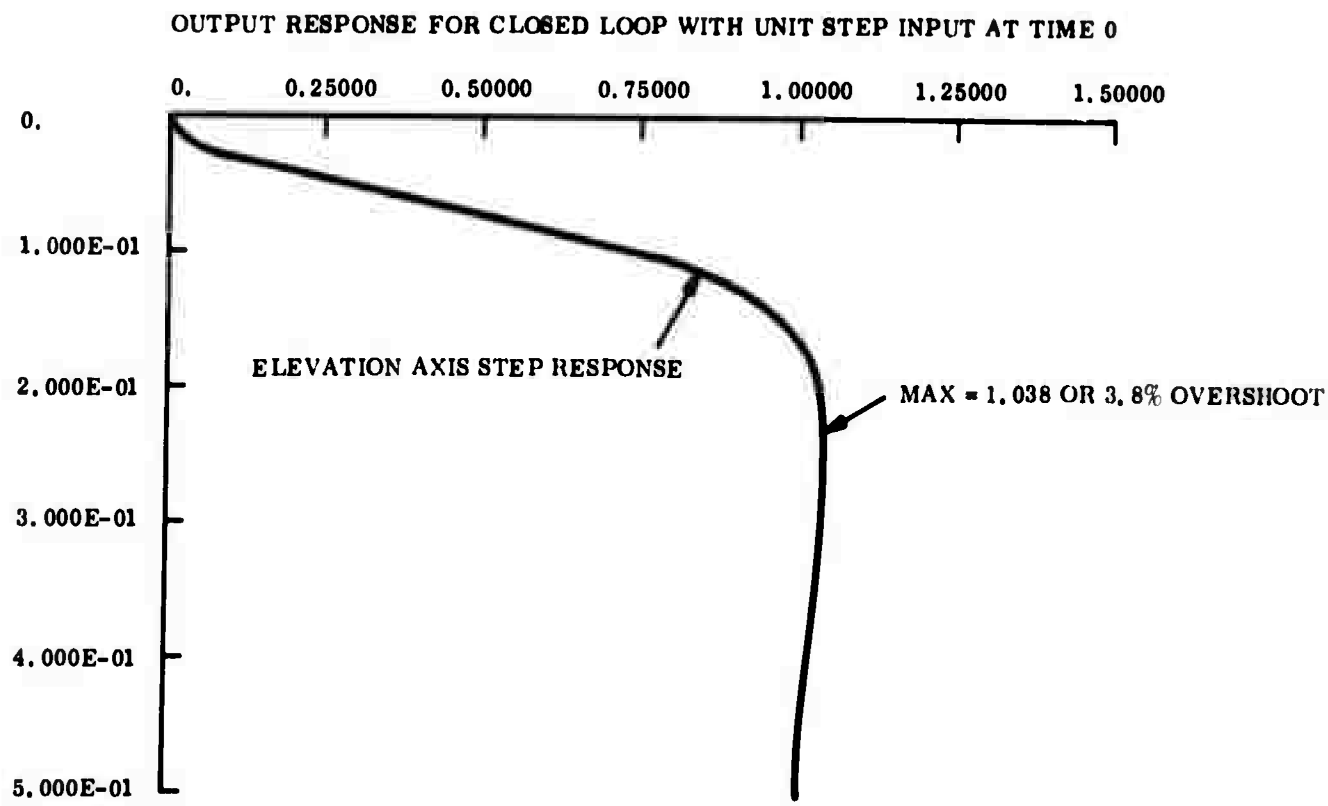


Figure 8-23. Elevation Position Loop Step Response (Corrected for Motor Plus Load Break)

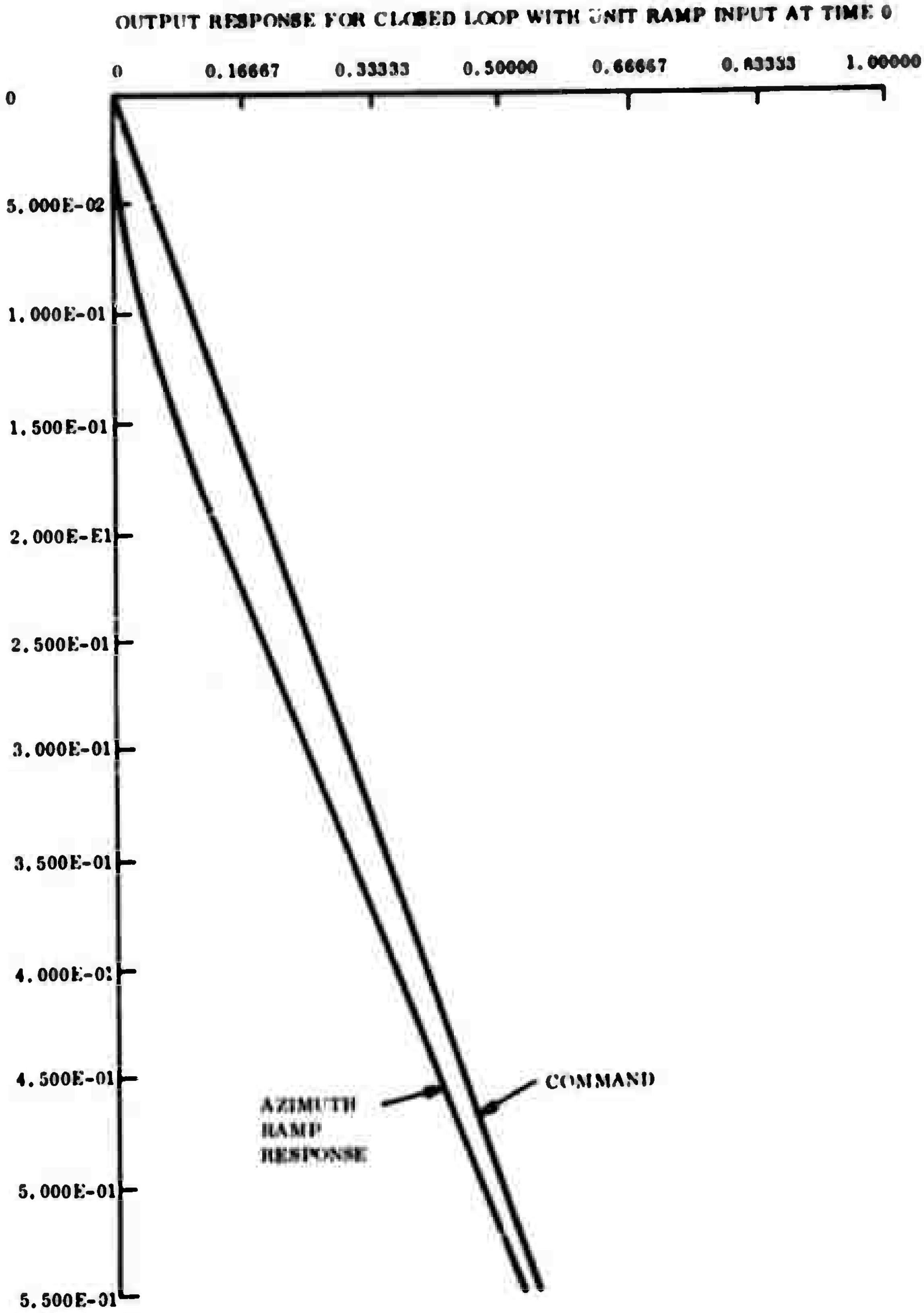


Figure 8-24. Azimuth Axis Range Response

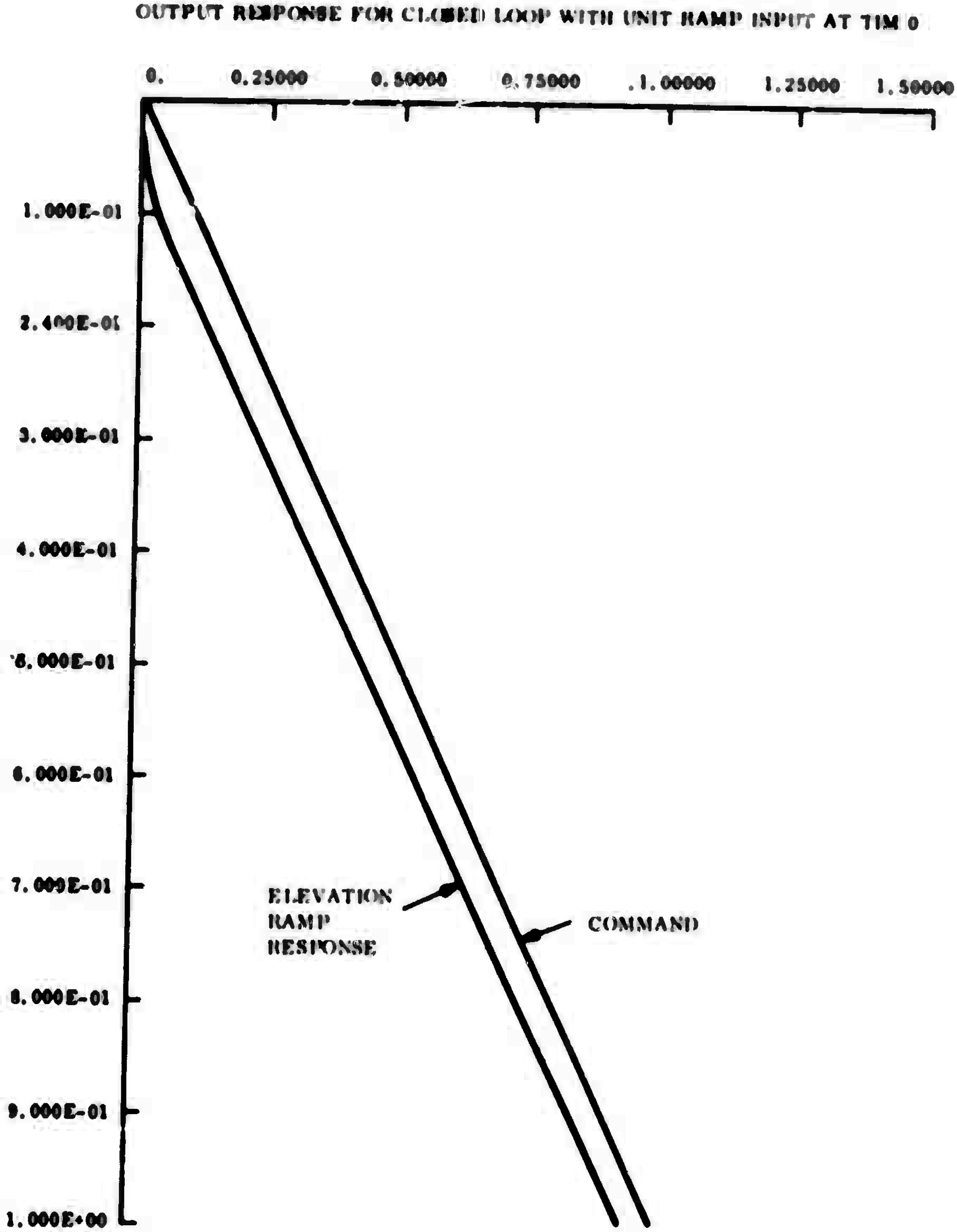


Figure 8-25. Elevation Axis Ramp Response

azimuth. Reducing the elevation error can only be accomplished by introduction of more tach feedback, resulting in an increase in the over-shoot to a step command. Following error in elevation comparable to that in azimuth can be achieved by modifying the values of R_1, R_2 and C in the rate summing and feedback networks discussed in Section 8.3.6. If changed as shown below, the step response over-shoot will change from 4% to an estimated 11%, while position loop bandwidth will remain approximately the same.

	R_1	R_2	C
Elevation now	1 meg	500K	0.2μ fd
Elevation with following error comparable to azimuth	200K	1 meg	1 μ fd

8.4.3 Static Pointing Offset. An approximation of the motor - load friction was determined by recording the amount of voltage necessary to maintain a minimum rate about the azimuth axis. This voltage level (6 volts) can be converted to a static position error by dividing by the position loop gain preceding this voltage as shown in Figure 8-26.

$$\text{Elevation error} = \frac{6 \text{ volts} \left(\frac{\text{rad}}{\text{volt}}\right)}{(325)\ (3.125)\ (10)} = 0.6 \text{ milliradian} = 0.034 \text{ degree}$$

$$\text{Azimuth error} = \frac{6 \text{ volts} \left(\frac{\text{rad}}{\text{volt}}\right)}{(472)\ (3.125)\ (10)} = 0.41 \text{ milliradian} = 0.023 \text{ degree}$$

Here too, the elevation servo would be improved if the higher gain indicated in Section 8.4.2 were implemented. For that specific case, elevation static error would be reduced to 0.3 milliradian or comparable to the azimuth loop.

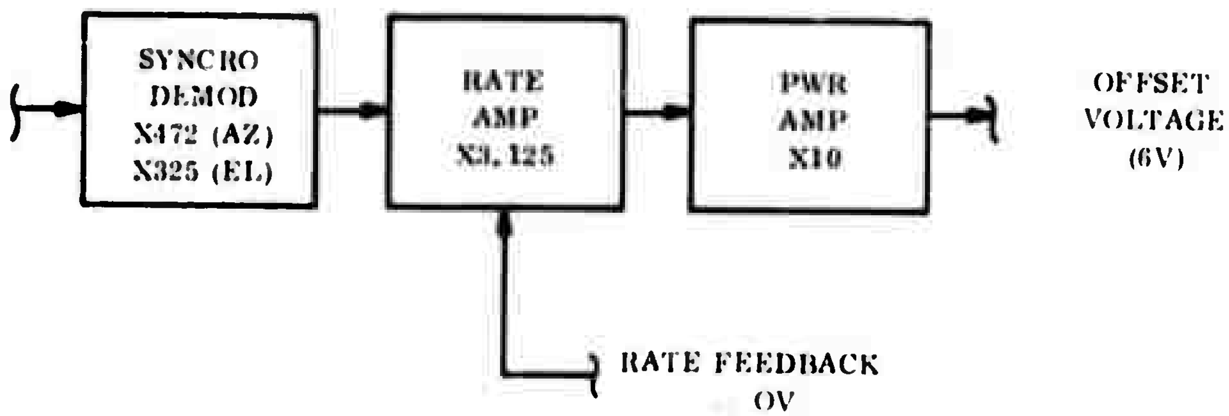


Figure 8-26. Static Offset

8.5 Summary

With the existing gain settings, the telescope drives should present a smooth output with minimal over-shoot to step and ramp commands. Variation in these responses can be achieved without seriously affecting loop stability by adjusting the power amplifier gains (nominally set at their maximum value of 10 v/v). Additional modification of selected resistors and capacitors in the elevation rate and position loops can be made to arrive at a faster and tighter servo without affecting stability. This modification will, however, cause a larger step responser over-shoot than now exists. It is recommended that the present loop gains be maintained until the telescope mount is installed and operated with the accompanying analog computer. If at that point its response does not seem adequate, modification of the resistor/capacitor networks suggested should be considered.

9.0 VIDEO SUBSYSTEM

The video console houses the ampex video recorder, timing digital readouts and a vidicon camera (see Figure 9-1). The purpose of the vidicon camera is to monitor the digital displays. The output is mixed the video signal of the I.O. camera and recorder on the video recorder. With the exception of initial turn on, the video console requires no attention during mission coverage. Refer to Figures 9-2 through 9-4.

The television electronic spot generator contains four one shot multivibrators and two pulse shaping circuits at the input. The shaping circuits generate a clean horizontal and vertical drive pulses to drive the one shots. Inthe vertical channel, the V drive pulse triggers the V position one shot (7 to 9 milliseconds wide) to generate the position (vertically) of the gate pulse. The output of this one shot triggers a second one-shot approximately 100 microseconds wide which is used as a gate to allow at least one or two horizontal pulses to pass through gate. The H drive pulse triggers the H position one shot multivibrator (30 to 40 μ secs.) to allow positioning (horizontally) of electronic spot. The position one shot triggers a second one shot approximately 0.5 μ sec wide pulse, but this one shot is also gated with the vertical gate pulse. This combination allows only one or two (0.5 μ sec) pulses to be generated and capacity coupled to television monitor for display.

A Model 4PE26A1, Portable Three-Inch Image Orthicon camera was imployed for direct observation of the cloud. Before each mission the camera was adjusted for low light level operation. To accomplish this alignment a lens "cap" with small holes drilled through the surface was used to attenuate the day light sceen to nighttime conditions. Beam current, target voltage, etc. of the S 20 photo-tube were then adjusted.

Focusing of the objective lens was found to be significantly different for each spectral filter and the open position. The positions were appropriately marked, however necessitate an additional crew member to adjust the focus during mission coverage.

Appropriate schematics for the television system are available in the reference manual.

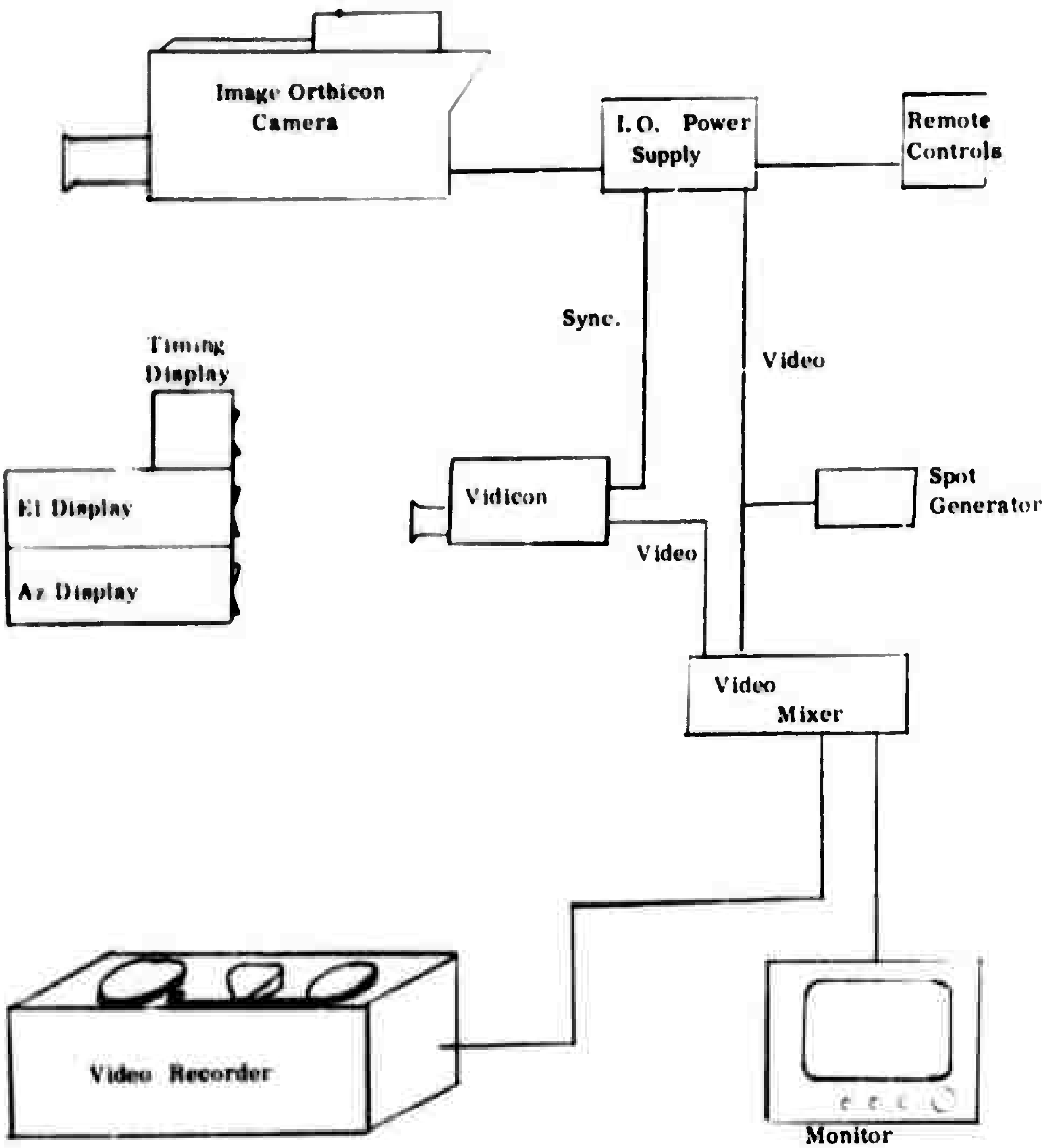


Figure 9-1. Video System

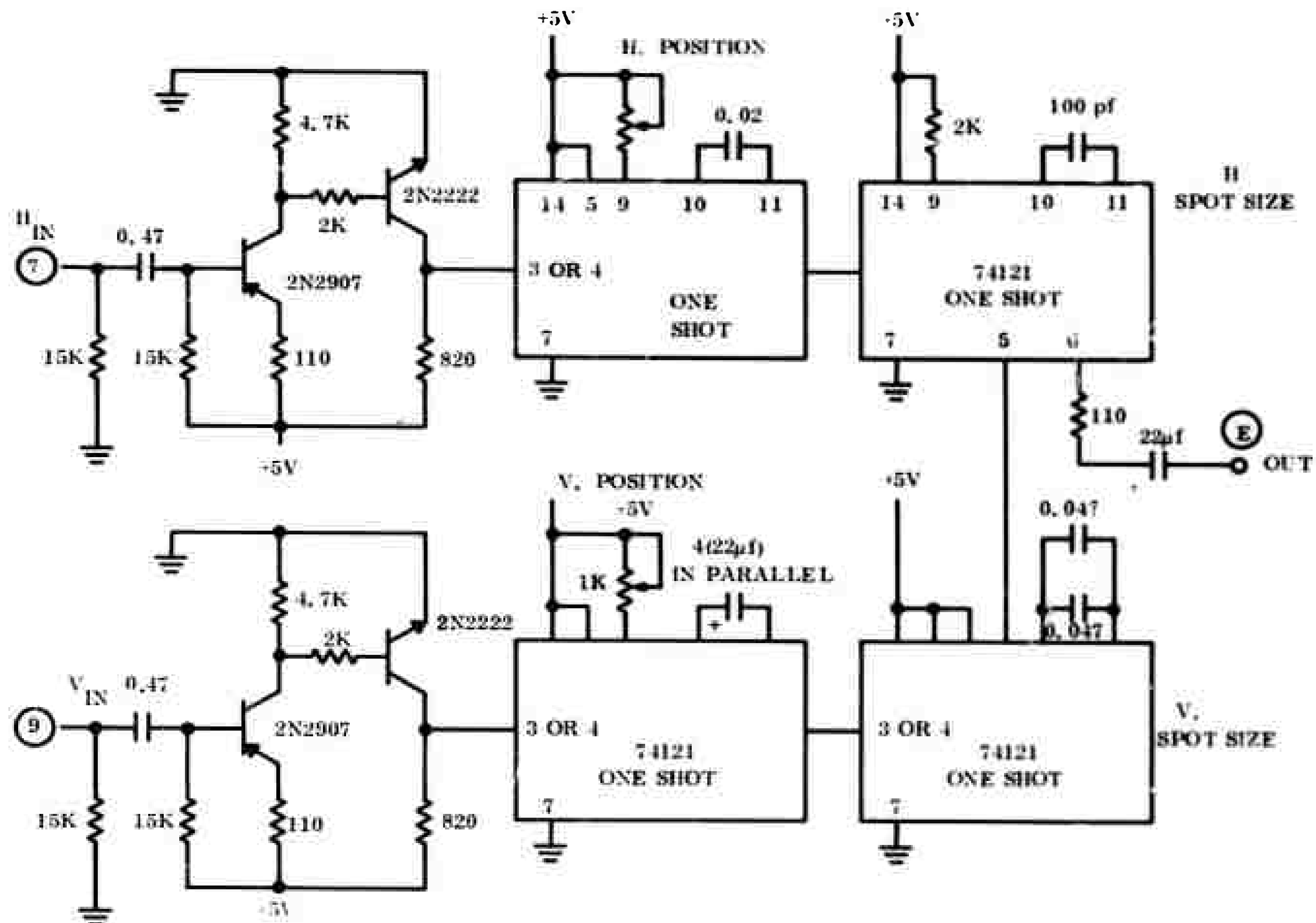


Figure 9-2. Spot Generator

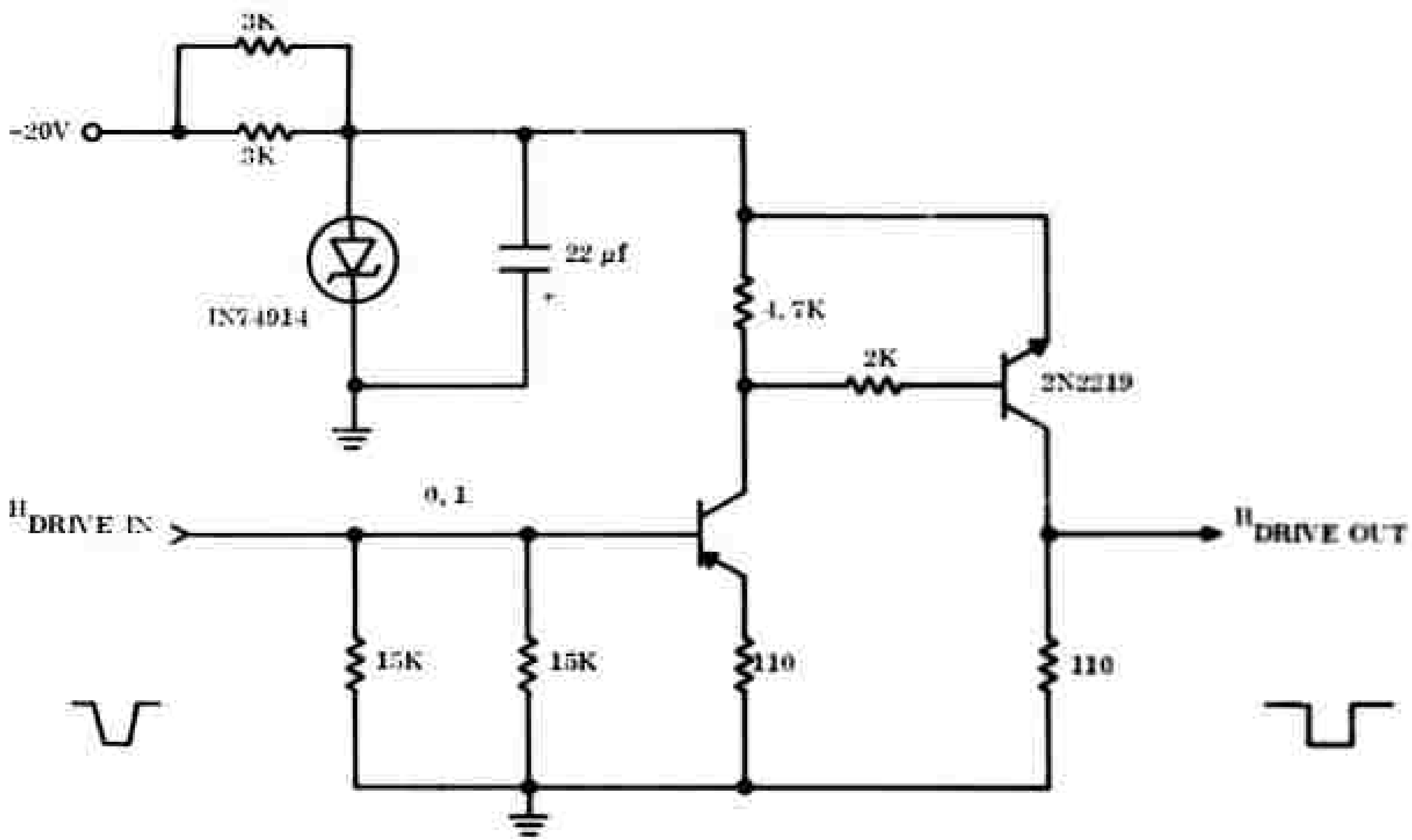


Figure 9-3. H-Drive Pulse Shaper/Line Driver

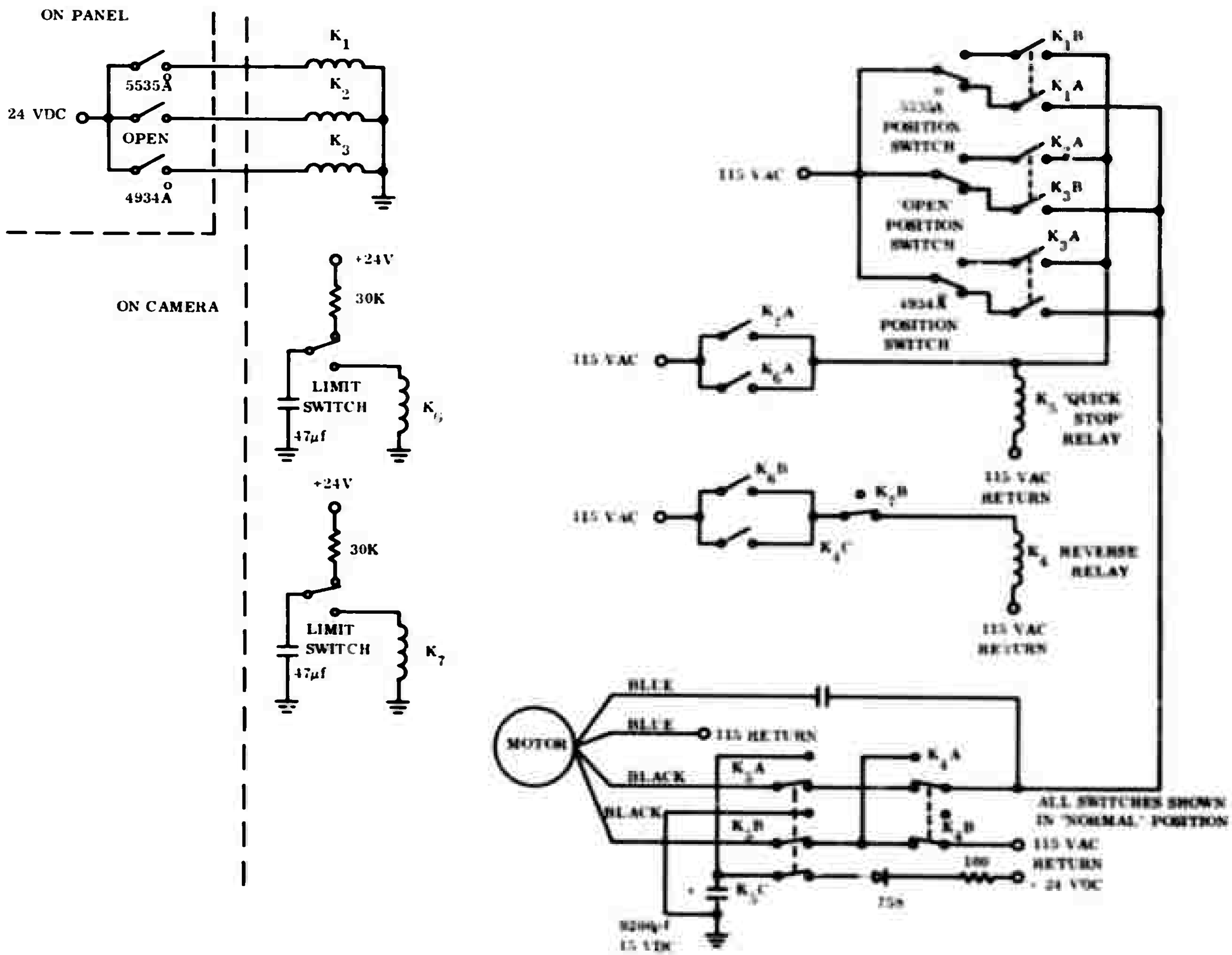


Figure 9-4. Filter Wheel Control

9.1 Manual Sighting Station

A manual sighting station is provided to direct the Secede pedestal. The sighting station contains a telescope which has a visual point of light projected at infinity which is superimposed on the point to be tracked. In addition, the pedestal carries a 35mm framing camera with an intervalometer to control both the exposure and frame rate. The sighting station itself served previously as a director for the search light system. It was modified with the addition of a high resolution potentiometers and a 1 and 36 speed control transformer on each axis. The sighting station can be used in either the control transformer mode or the high resolution potentiometer mode at the discretion of the controller. In the control transformer mode the sighting station directs the pedestal through a direct comparison between the CT position and the synchro generator positions in the pedestal. An error signal is derived from the difference in the two. In the high resolution potentiometer mode, the position of the potentiometers control the position of the control transformers in the scan computer. An error signal is then derived between the synchro generators in the mount and the control transformer of the scan computer. In either mode the scan computer follows the position of the potentiometers.

The manual sighting station is a tripod structure in which the controls for elevation and azimuth are by virtue of hand wheels. During actual mission coverage the operator at this station is responsible for tracking the initial rocket during ascent so that pedestal will be directed to the point of initial burst. In addition, if events of interest far beyond the television system field of view are occurring, then the manual sighting station controller will direct the mount to such a position. In actual performance, however, it was found that the predicted point of release was always well in the field of view of the television system. During the actual taking of data the operator of the control console had a much clearer view of the exact direction of scanning and pointing than the view of the manual sighting station controller. It was found through experience, therefore, that the manual sighting station was employed primarily as a back-up mode of operation to that of the television display. Further improvements in the actual display of the television system will probably relegate the manual sighting station to a position of emergency control only.

10.0 SYSTEM INTERCONNECTIONS

A block diagram of the system interconnections is shown in Figure 10-1, "Interconnection Diagram". Where possible bulkhead connectors have been eliminated in favor of direct connection to a particular chassis within a console. In particular, the video console has direct connections to azimuth/elevation readout and timing digital display chassis. A total of 92 interface connections were eliminated. Maximum use of of the Bendix E series crimp connector reduced the assembly time of each required connector by approximately 30% while time for any cable rework, where necessary, was reduced by 150% over the conventional solder type connectors.

The following series of figures, Figures 10-2 through 10-10, document the construction of the interconnection houses.

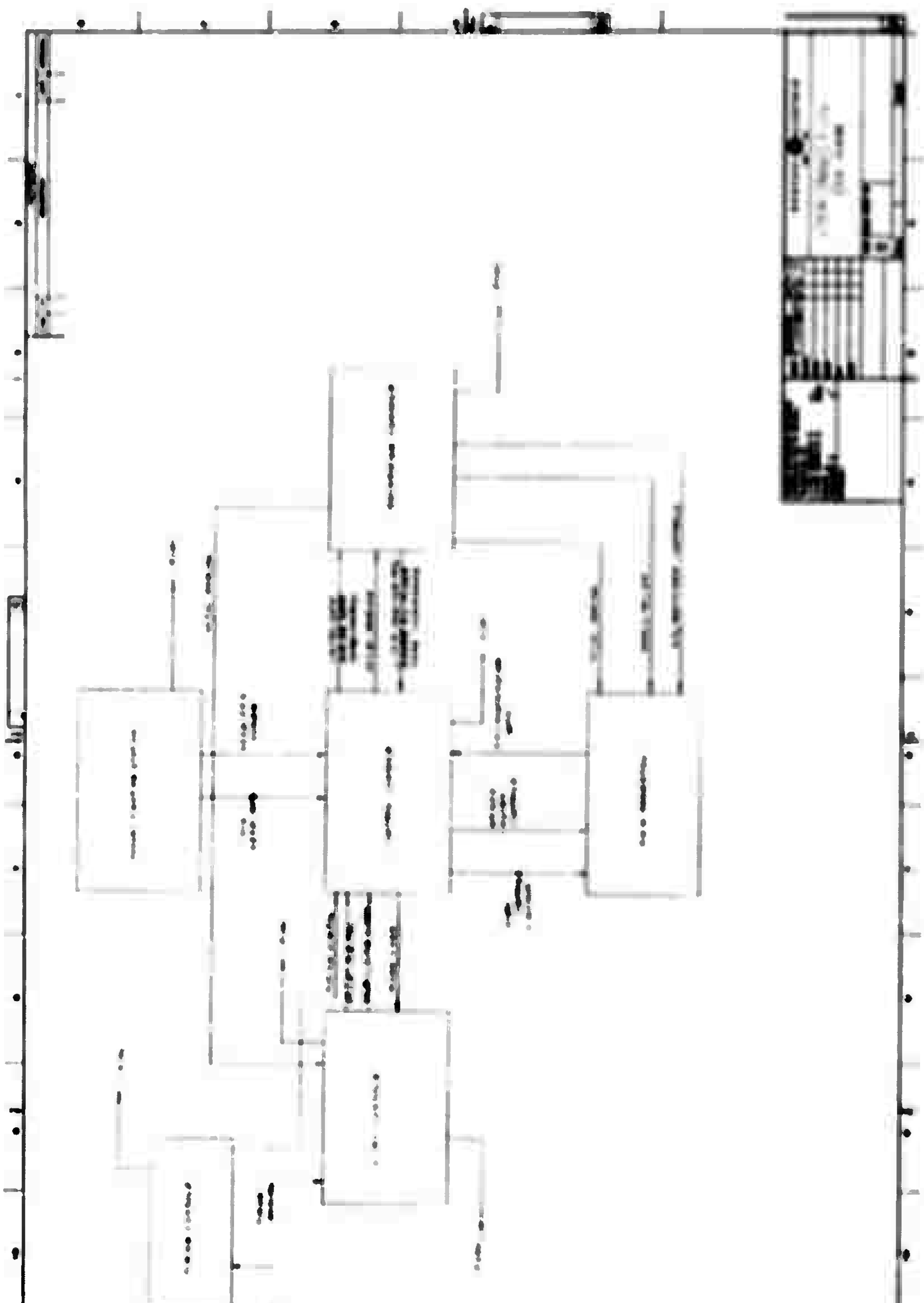


Figure 10-1. Interconnection Diagram

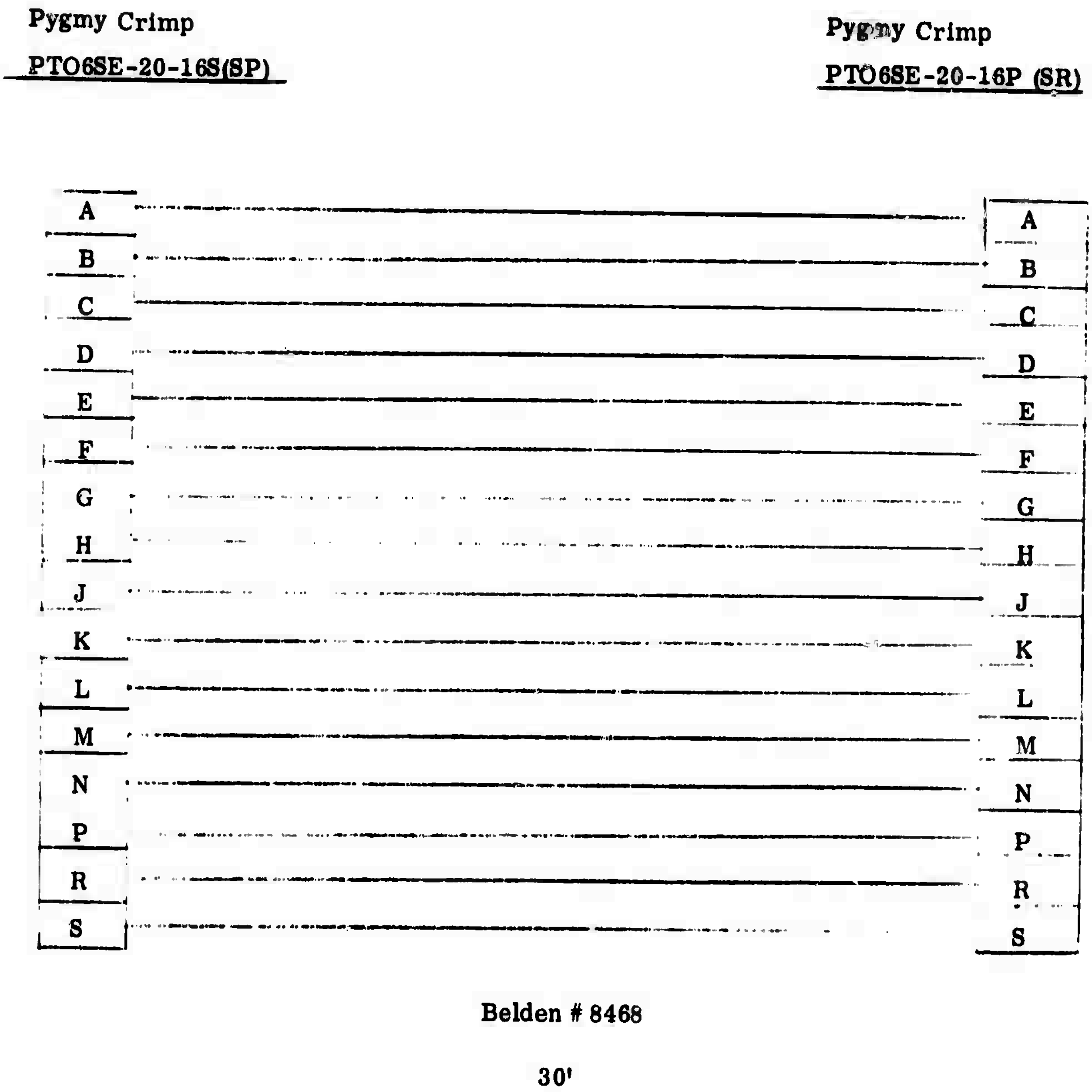
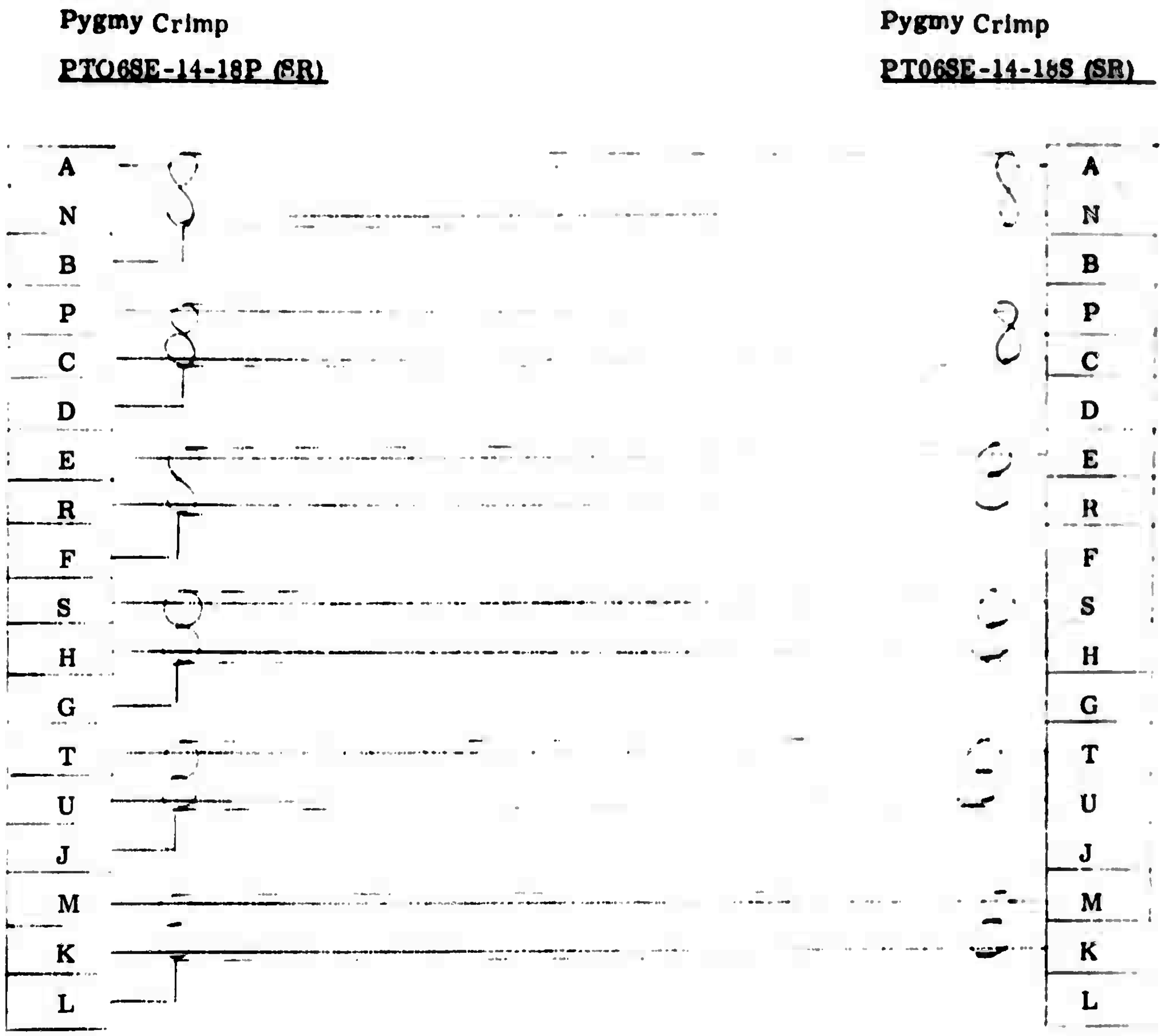


Figure 10-2. Servo Amplifier Cable



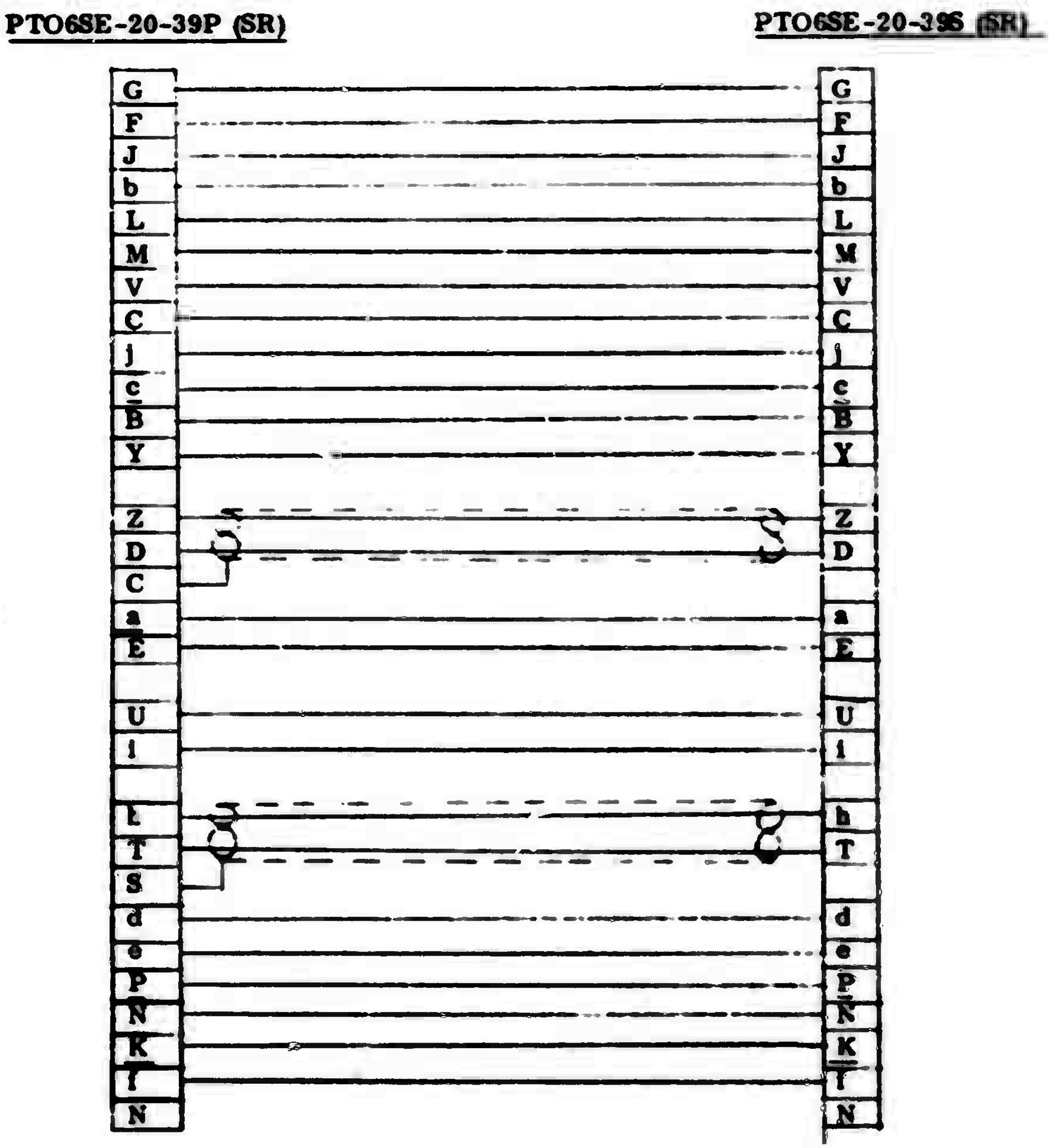
All #20 Twisted Shielded Pairs

Quantity 1

Length 30'

Sheathed (Vinyl)

Figure 10-3. A_Z/El Pots Manual Sighting Station to Control Console Cable



CONTROL CONSOLE TO RECORDING CONSOLE

Quantity 1

Length 6'

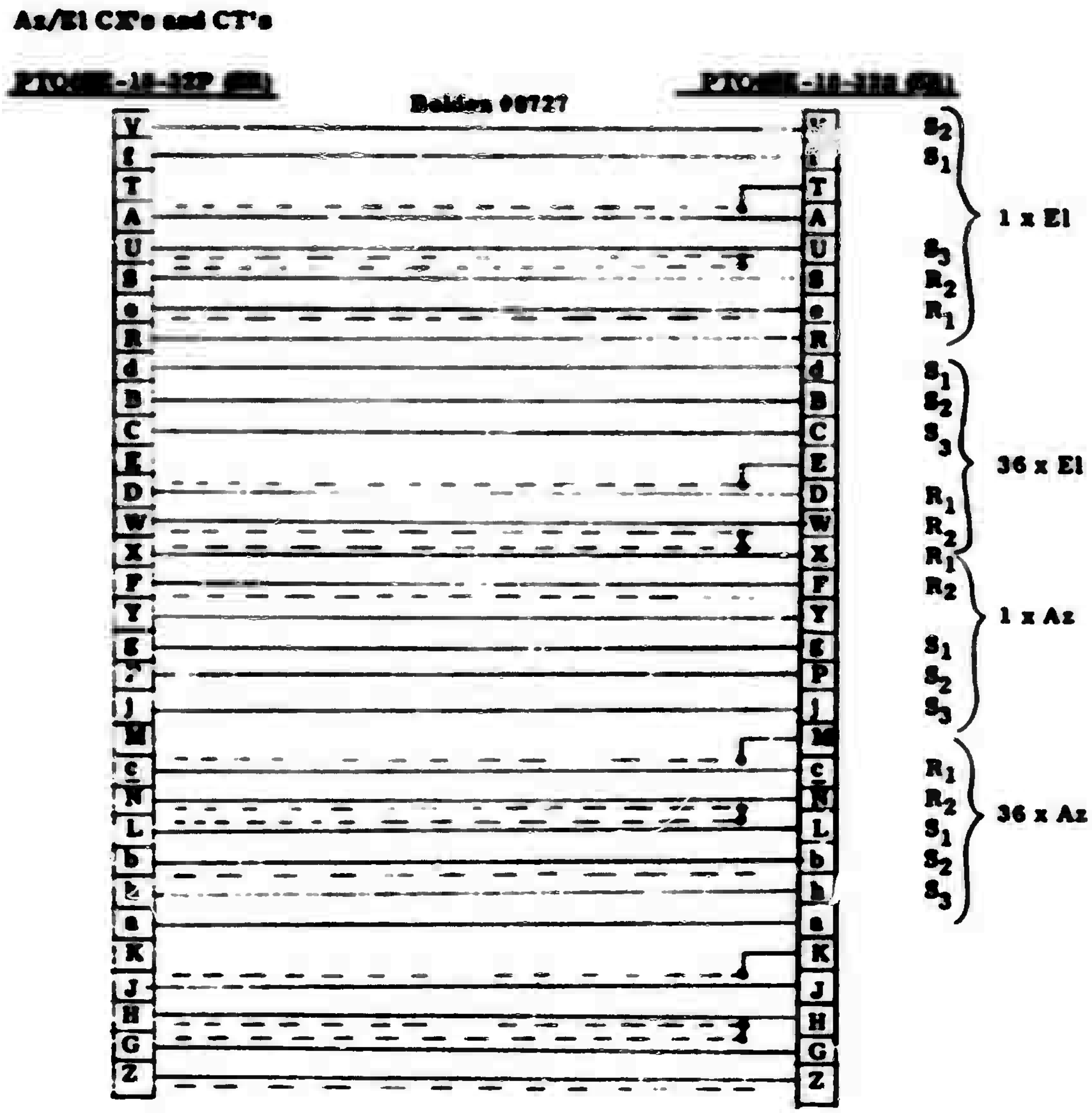
All Single wires #20

All Twisted Shielded pairs #20

Sheathed with Vinyl

Not laced

Figure 10-4. Signal Cable, Control Console to Recording Console



NOTE

Four Cables

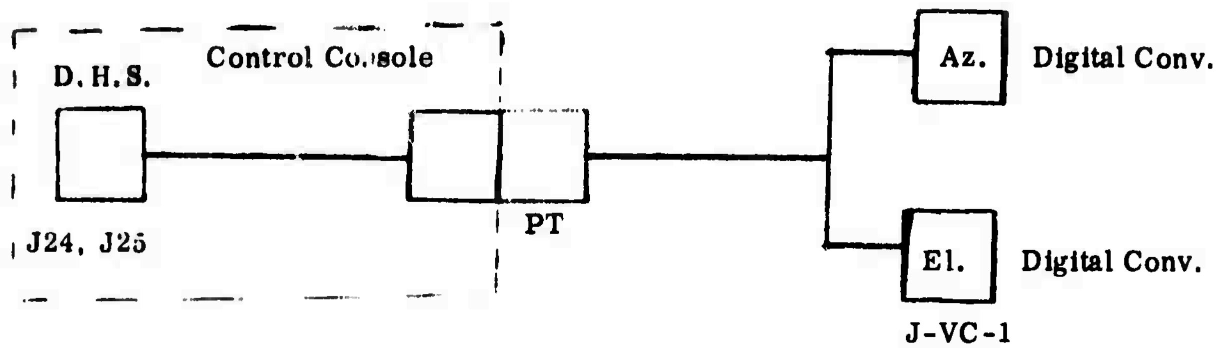
a) 1 ea. 5 feet
b) 1 ea. 3 feet
c) 2 ea. 30 feet

a) Az/El CT's Recording Console to Control Relay Box

b) Az/El Scan Computer/Relay Box Control

c) 1)Az/El CX's Main Pedestal to Recording Console
2)Az/El CT's Manual Sighting station to Control Relay Box

Figure 10-5. Synchro System Cabling

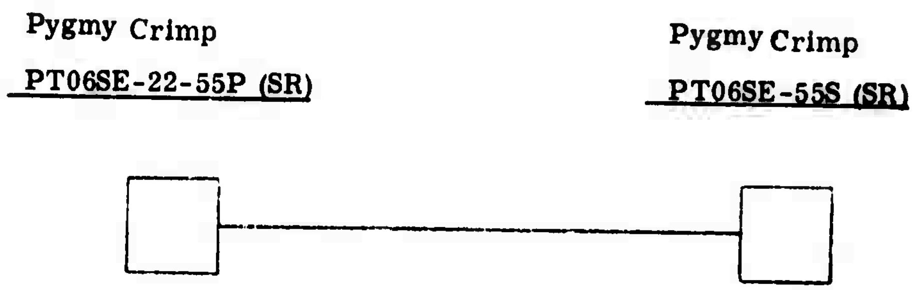


J-24	PT06SE-20-41S (SR)			J-VC-1 MS-3106A-28-21-PX
B	d	Az	AC_1 (Hundreds)	a
H	D	Az	AC_2 (Hundreds)	b
18	a	Az	AX_1 (Tens)	S
14	c	Az	AX_2 (Tens)	T
8	i	Az	AX_4 (Tens)	U
4	e	Az	AX_8 (Tens)	V
J-25				
13	T	Az	AI_1 (Units)	K
7	S	Az	AI_2 (Units)	L
2	j	Az	AI_4 (Units)	M
D	N	Az	AI_8 (Units)	N
I	k	Az	AT_1 (Tenths)	E
E	E	Az	AT_2 (Tenths)	F
22	X	Az	AT_4 (Tenths)	G
17	r	Az	AT_8 (Tenths)	H
21	f	Az	AH_1 (Hundredths)	A

Figure 10-6. A_Z/E1 Digital Cabling

J-25	PT06SE-20-41S (SR)			J-VC-1 MS-3106A-28-21PX	
16	g	Az	AH_2 (Hundredths)	B	
10	S	Az	AH_4 (Hundredths)	C	
6	U	Az	AH_8 (Hundredths)	D	
		El		J -VC - 2	
A	G	El	EC_1 (Hundredths)	a	
F	F	El	EC_2 (Hundredths)	b	
19	g	El	EX_1 (Tens)	S	
15	N	El	Ex_2 (Tens)	T	
9	P	El	Ex_4 (Tens)	U	
5	h	El	Ex_8 (Tens)	V	
8	R	El	EI_1 (Units)	K	
4	Z	El	EI_2 (Units)	L	
B	H	El	EI_4 (Units)	M	
H	K	El	EI_8 (Units)	N	
J-26					
2	Y	El	ET_1 (Tenths)	E	
D	b	El	ET_2 (Tenths)	F	
J-25					
18	P	El	ET_4 (Tenths)	G	
14	t	El	ET_8 (Tenths)	H	
J-26					
22	m	El	EH_1 (Hundredths)	A	
17	M	El	EH_2 (Hundredths)	B	
13	L	El	EH_4 (Hundredths)	C	
7	J	El	EH_8 (Hundredths)	D	
and	A	El	Spare	R	J-VC-1 Gnd
	B	El	Spare	R	J-VC-2 Gnd
	C		Spare		

Figure 10-6. A_Z/E1 Digital Cabling (Continued)



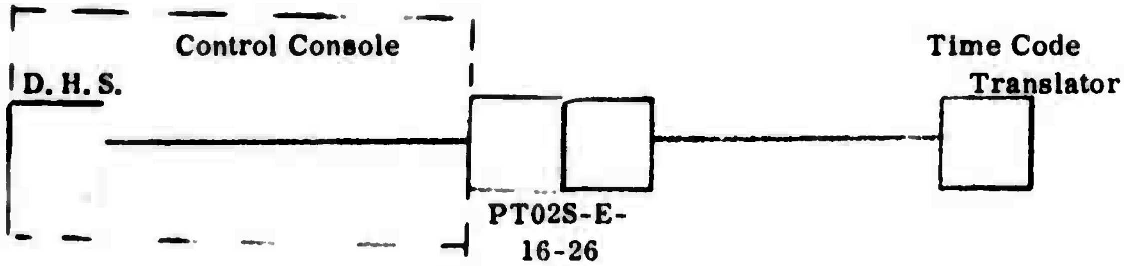
a. Pin to Pin connections

b. All #20 Wire

c. Sheathed

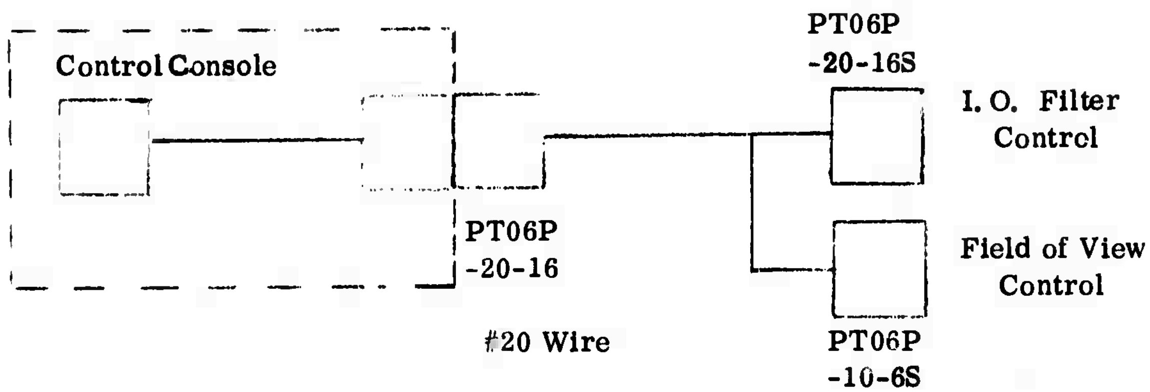
d. Length - 6 Feet

Figure 10-7. Control Console to Recording Console Cabling



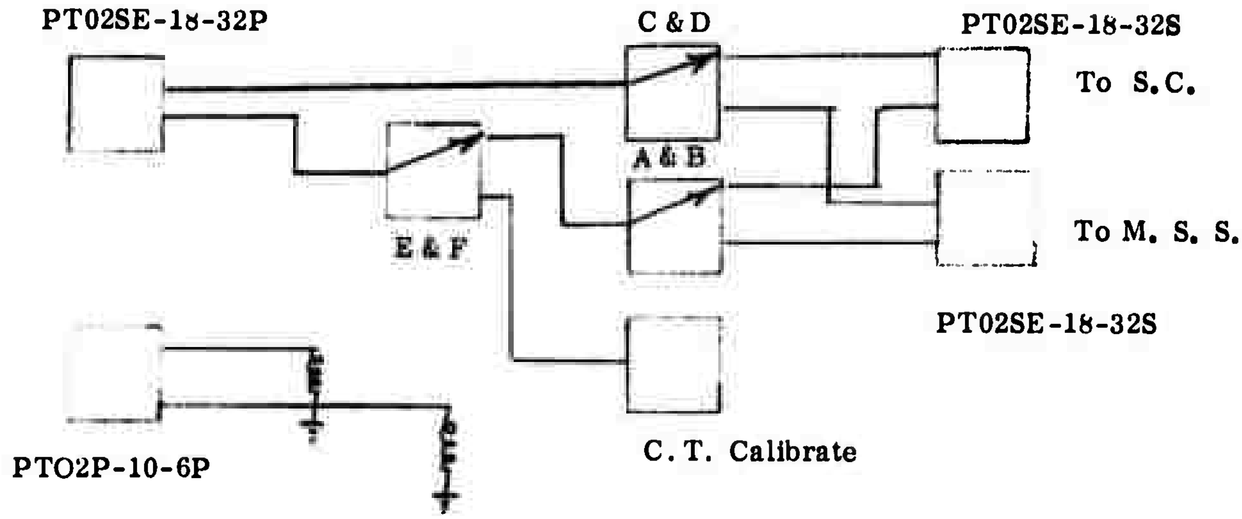
J-23	PT06SE-16-265 (SR)			Code Translator
17	R	MX_1	Minutes Tens	g
13	G	MX_2	Minutes Tens	r
7	H	MX_4	Minutes Tens	s
6	B	MI_1	Minutes Units	k
1	S	MI_2	Minutes Units	m
E	V	MI_4	Minutes Units	n
22	N	SX_1	Seconds Tens	h
16	W	SX_2	Seconds Tens	i
10	Y	SX_4	Seconds Tens	j
9	Z	SI_1	Seconds Units	c
5	E	SI_2	Seconds Units	d
A	b	SI_4	Seconds Units	f
F	a	SI_8	Seconds Units	g
B	u	ST_1	Seconds Tenths	Y
H	D	ST_2	Seconds Tenths	Z
19	C	ST_4	Seconds Tenths	a
15	F	ST_8	Seconds Tenths	b
18	T	SH_1	Seconds Hundredths	u
14	c	SH_2	Seconds Hundredths	v
8	P	SH_4	Seconds Hundredths	W
4	X	SH_8	Seconds Hundredths	X

Figure 10-8. Timing Cabling



Control Console		PT02P-20-16S	PT06P-20-16S
TB-CC-1-5	GND	A	A
TB-CC-1-7	+24 VDC	B	B
TB-CC-3-1	115 VAC	C	C
TB-CC-3-3	115 Ret	D	D
10A-1	5535 Å Switch	J	J
8B-3	Open Switch	K	K
10B-3	4934 Å Switch	M	M
			PT06P-10-6S
14A-1	NF/WF Switch	E	C
TB-CC-1-7	GND	G	D
115 VAC		H	A
115 Ret		F	B

Figure 10-9. Field of View and I. O. Filter Wheel Cabling



PT02P-10-6P

A	Gnd
B	CT's Manual Switch
F	Calibrate Switch

Relay A

→ A-10 → F-14 → e
A-13 → F-17 → u
A- 7 → F-2 → t
A-16 → F-8 → S
A- 4 → F5 → V
A- 1 → F-11 → R

Relay B

B-7 → E-11 → A
B-4 → E-14 → B
B-1 → E-17 → C
B-10 → E-8 → d
B-16 → E-5 → N
B-13 → E-2 → D

Relay C

C-1 → P
C-4 → j
C-7 → X
C-10 → g
C-13 → F
C-16 → c

Relay D

D-1 → h
D-4 → z
D-7 → L
D-10 → a
D-13 → b
D-16 → N

Relay F

F-3 → S_1
F-6 → S_2
F-9 → R_2
F-15 → R_1
F-18 → S_3

Relay E

E-5 → R_1
E-6 → R_2
E-9 → S_1
E-15 → S_2
E-18 → S_3

Figure 10-10. Synchro Relay Box

11.0 RECOMMENDATIONS FOR FUTURE PEDESTAL USE

As with any system which is designed and built for experimental measurements in the field, several problems which were not anticipated caused the system to operate in a less than optimum fashion. Prior to use of the mount for additional measurements several modifications should be incorporated into the system to eliminate several of these difficulties. Several of the recommendations which will be made will solve problems which can be categorized as being optimization of the system, while others can be categorized as being essential to future mission planning. Some of the recommendations could if implemented be quite costly. An implementation of such changes in these systems will depend a great deal on decisions which must be made as to whether or not the system needs to be absolutely optimized in order to make useful measurements.

Perhaps the most severe problem encountered during the Secede II experiment program was that of being unable to read the digital data in real time to determine whether or not all the functions were being properly recorded on the digital tape recorder. Due to this lack of real time capability, many days were spent in which the personnel at the site were in doubt as to whether or not any data was being placed on the Kennedy tape recorder. As a result the confidence in the readiness status of the station was not high.
Many trips were made to two different computer facilities, one at the Naval Mines Laboratories the other at Eglin Air Force Base in which the computer soft ware which should have been able to read the digital tape was also in doubt. A second digital tape recorder was brought to Florida from the University of Pittsburgh and placed on line in parallel with the original digital tape. Even with the redundancy in data recording, the lack of real time capability

of reading either of the tapes left the station still in a doubtful status condition. One way to circumvent this problen. is to provide a small computer which would be able to read the digital tape on site and either print out or write data on a chart recorder in an intelligent, interpretable format. Such a computer would be a major addition to the Secede II system.

Such a computer could in principle be used to perform the function of the present analog scan computer. To incorporate the dual use of a small digital computer that is, for reading digital data and for doing scan computation and direction of the mount servo system, a completely new servo systems design would be necessary. Presently the servo design computes position from the readout of analog control transformers and control generator combinations. This system would nave to be changed into a digital format best implemented perhaps by use of digital shaft encoders directly on the mount. The interface between the digital computer and digital position encoders would have to be provided. Such a design is possible, however on the present Secede II system it would entail a major redesign of the entire servo system and data handling system.

The television system on the Secede II mount did not operate as well as was expected. The primary reason for this was due to a 8" focal length lens giving a field of view of only 8°, which was in general smaller than the targets of interest. This full field of view image gave very little contrast against the dark night sky and as a result made it extremely difficult to observe the ion clouds prior to their striation. The 8" focal lengtn was chosen to match the resolution of the I.O. camera to the narrow field resolution of the interferometer system. This choice proved to be unfortunate. In future Secede experiments a much larger field of view perhaps on the order of 16 to 20 degrees is certainly in order. The implementation of such a wide field of view lens

however, may cause problems with the present filtering system. Filters are presently in the converging beam of the objective lens. A shorter focal length lens would require that the filters be more broad band than are presently employed. I personally do not feel that this is any particular problem in that there are few extraneous sources in the field of view which will radiate in the spectral region of interest. To implement an additional lens is quite inexpensive in that only a new lens need be bought and an adapter made for the present turret mount of the I. O. system.

Although the I. O. system operated very nicely in Philadelphia, problems were encountered with the synchronization of the I. O., vidicon, video mixer, and the tape recorder system. This synchronization problem arose from the fact that a diesel generator was employed as the primary source of power. The vidicon, being used as the master sync generator, is designed to be locked to the 60 cycle line frequency. The horizontal and vertical sync pulses are stepped up in the I. O. camera by a factor of X275 and any variation of frequency control at the diesel generator is magnified greatly in the I. O. camera. This problem can be eliminated by providing a master composite sync separate from the vidicon system which will be used to drive the entire video system. Problems were also encountered with the inexpensive monitors which were not designed for use at low light levels. A monitor with improved video amplifier characteristics should be incorporated into the control station. Also, a second monitor should be provided (not in this case for non essential personnel but) for quick look data analysis after the mission and a monitor station for the manual sighting station operator. Prior to its further use the image orthicon camera should be refurbished by a detailed laboratory alignment. Such an alignment should eliminate some of the problems encountered due to power supply drifting and other related idiosyncracies.

The control console panel lights were far too bright for night time operation. To reduce the intensity of these lights each of the switches was painted so that only a small portion of the lens caps was illuminated. In some cases, however this caused the switch to stick in a latch position which hindered the operation of the control console. A better solution would be to provide a rheostat for all the panel lights which could be lowered for night time operation and allowed full brightness during daylight conditions. In addition, each of the lamps should be operated in a two level mode. In this way when the switch is not activated a very low light level would emanate from the switch by which the operator could quickly identify the physical position of each of the switches. When activated however, the lights would appear brighter than in the inactive mode. This would eliminate some of the fumbling in the dark that an operator experiences even when thoroughly familiar with the use and position of each of the switches.

Although the scan computer, operated satisfactorily in a scan mode, the azimuth response was quite poor on the joy stick. This problem is caused by the use of the two inexpensive Beckman Model 939 instrument servo's in the initial portion of the azimuth drive. This problem could be eliminated by using the more expensive Industrial Control Units. A much better response in azimuth would facilitate directing the mount to the initial point desired during mission coverage. The time spent in jockying the boresight point back and forth about the desired point is wasted in that no data can be recovered as the mount is being slewed. Implementation of these new servos is complicated by the fact that there is extremely little room available in the present control console.

Many of the operational problems which were encountered could have been eliminated if more time was spent in actual operation under nightime conditions prior to bringing the system to the field. It is hoped that for any additional work which is anticipated for the Secede II system that a greater amount of time could be allocated for the initial integration of the system.